DOCUMENT RESUME

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DESCRIPTORS	*Auto Mechanics; Behavioral Objectives; Course Descriptions; Curriculum Guides; *Electrical Systems; *Electric Batteries; *Electric Circuits; *Engines; Equipment Maintenance; *Industrial Arts; Inspection; Learning Activities; Lesson Plans; Motor Vehicles; Postsecondary Education; Programed Instructional Materials; Repair; Secondary Education; Skilled Occupations; Study Guides; *Vocational Education; Workbooks
IDENTIFIERS	Military Curriculum Project

ABSTRACT

This plan of instruction, lesson plans, and student materials (study guides, workbooks, and programed texts) for a secondary-postsecondary level course in engine mechanics is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. It is the second of a four-part course (see Note for other sections) covering general vehicle mechanics, including inspection, maintenance, and repair. The plan of instruction suggests number of hours of class time devoted to each lesson in one block of instruction (Block III, a total of 74.5 hours of instruction): Auto Electrical Units, containing five lessons on fundamentals of automotive electricity, batteries, and basic electrical circuits; battery and magneto ignition system; cranking motors and starting system; DC charging system; and AC charging system. It also details criterion objectives and support materials needed. Lesson plans outline teaching steps. Student materials include study guides containing objectives, text material, and review questions; two workbooks containing shop procedures; and two programed texts. Military manuals, commercial texts, and audiovisuals are suggested, but not provided. (YLB)

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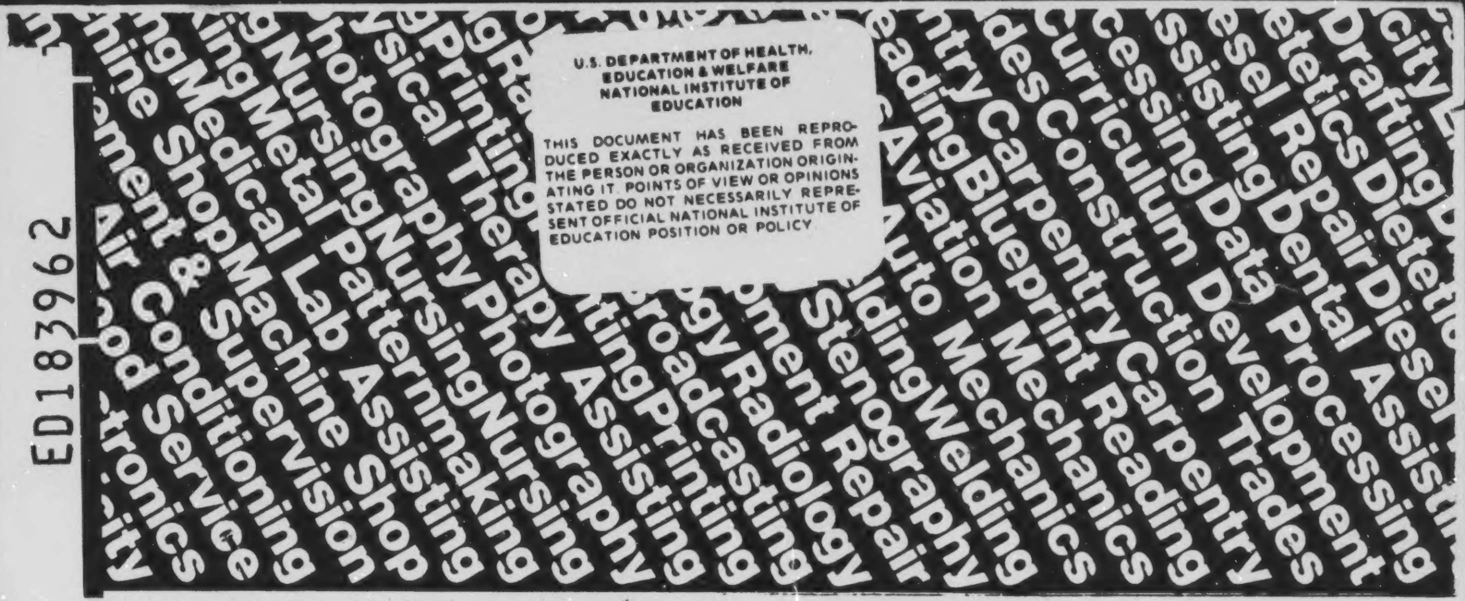

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ED183962

Military Curricula for Vocational & Technical Education

BEST COPY AVAILABLE

General Purpose Vehicle Mechanic

Block III, 8-10

CE 024 829

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

MILITARY CURRICULA FOR VOCATIONAL & TECHNICAL EDUCATION

GENERAL PURPOSE VEHICLE MECHANIC, BLOCK III

Classroom Course 8-10

Developed by:

United States Air Force

Development and Review Dates:

November 6, 1975

SCT No.:

[illegible]

Occupational Area:

Engine Mechanics

Target Audiences:

Grades 11-adult

Print Pages:

329

Cost:

$6.75

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
			No. of pages									
Block III – *Auto Electrical Units*			44									
Fundamentals of Automotive Electricity, Batteries, and Basic Electrical Circuits	●	●	●		●		●			*	●	●
Battery and Magneto Ignition Systems	●	●	●		●		●			*	●	●
Cranking Motors and Starting System	●		●		●		●			*	●	
DC Charging System	●		●		●		●			*	●	
AC Charging System	●		●		●		●			*	●	

* Materials are recommended but not provided.

Expires July 1, 1978

Course Description

This section is the second of a four-part course covering general vehicle mechanics. The entire course covers inspecting, servicing, testing, adjusting, troubleshooting, and repairing automotive general purpose vehicles; gasoline engine tune-up and repair; manual and automatic transmission replacement and adjustment; lubrication system servicing and repair; cooling system servicing; power train repair; front end and steering system adjustments and repair; brake system adjustment and repair; warning and lighting system repair; hydraulic control repair; air conditioning system servicing; corrosion control; and preparation of vehicles for climatic conditions and shipment. This section of the course contains one block of instruction covering 74.5 hours.

Block III — *Auto Electrical Units* contains the following five lessons:

Fundamentals of Automotive Electricity, Batteries, and Basic Electrical Circuits (16 hours)
Battery and Magneto Ignition System (30 hours)
Cranking Motors and Starting System (8 hours)
DC Charging System (3 hours)
AC Charging System (17.5 hours)

This section contains both teacher and student materials. Printed instructor materials include lesson plans outlining the teaching steps and a plan of instruction detailing units of instruction, criterion objectives, duration of the lessons, and support materials needed. Student materials include one study guide containing objectives, text material and review questions; two workbooks containing shop procedures; and two programmed texts on fundamentals of automotive electricity and magneto construction, operation, and inspection and maintenance. Another reference on battery and magneto ignition systems was deleted because it was copyrighted.

Several military manuals and commercially produced texts are referenced, but not provided. Audiovisuals suggested for use with the entire course include 53 transparencies, 10 films and 205 slides. This section used in conjunction with the other three sections provides comprehensive coverage of vehicle inspection, maintenance, and repair. Some documents can be used individually as sub-units, remedial or individualized study. The entire course can be used in a group instructional setting or adapted for individual use.

GENERAL PURPOSE VEHICLE MECHANIC, BLOCK III

Table of Contents

Course Description Page 1

Plan of Instruction Page 10

Auto Electrical Units - Study Guides Page 67

Auto Electrical Units - Workbooks Page 227

Battery And Magneto Ignition Systems - Study Guide/Worksheet Page 268

Magneto Construction, Operation, Inspection And Maintenance - Programmed Text Page 296

Alternator And Regulator Testing Using Simpson CBS - Workbook Page 306

Fundamentals Of Automotive Electricity - Programmed Text Page 311

8-10 - 3

PLAN OF INSTRUCTION	COURSE TITLE General Purpose Vehicle ~~Repairman~~ Mechanic - Part I
BLOCK TITLE Auto Electrical Units	

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Fundamentals of Automotive Electricity, Batteries, and Basic Electrical Circuits	16 (12/4) Day 16, 17	Column 1 Reference — STS Reference 1a — 16a 1b — 12a 1c — 3, 4d, 9, 12c Instructional Materials 3ABR47330-SG-301, Fundamentals of Automotive Electricity, Batteries, and Basic Electrical Circuits 3ABR47330-WB-301, Fundamentals of Automotive Electricity, Batteries, and Basic Electrical Circuits 3ABR47330-PT-301B, Fundamentals of Automotive Electricity TO 33D6-3-4-1, UDT Audio Visual Aids Delco-Remy Chart, Section A, Fundamentals of Electricity Delco-Remy Chart, Section B, Batteries Films: TF1-5174A, Automotive Electricity for Military Vehicles TF1-4144-DF, Basic Electrical Circuits Transparencies, Batteries Training Equipment Trainer: 60-2597, Basic Automotive Electrical Board (10) 60-2573, Magnetic Field Demonstrator with Magnets (5) Mechanic's Common Handtools (1) Special Tools (1) Batteries (1) Battery Hydrometers (1) Battery-Starter Testers (2) Training Methods Discussion/Demonstration (6 hrs) Self-Instruction (2 hrs)
a. Without references, identify basic facts and terms relating to Ohm's Law, and principles of electricity and magnetism, to determine types of circuits and effects of voltage, amperage, and resistance in automotive electrical circuits, with 70% accuracy.	(6)	
b. Without references, identify basic facts relative to the construction, operating principles, and servicing of automotive batteries with 70% accuracy.	(3)	
c. Given TO, tools, equipment, storage battery, and observing personnel and equipment shop safety procedures, perform visual inspection and use test equipment to determine battery condition following the procedures, specifications, and recommendations in the TO.	(3)	

PLAN OF INSTRUCTION NO. 3ABR47330	DATE 2 January 1975	BLOCK NO. III	PAGE NO. 13

ATC FORM MAR 73 337 PREVIOUS EDITIONS OBSOLETE. ★ U.S. GPO: 1973—779-403/128 (Final Copy - 84% - 8 X 10½) (Final reduction to include area above this line)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		Performance (4 hrs) Outside Assignment (4 hrs) Instructional Environment/Design Classroom (8 hrs) Laboratory (4 hrs) Instructional Guidance Use PT, review, and demonstrations as required to teach electrical fundamentals and battery operation, maintenance, and testing. Complete training objectives using workbook and study references. Point out and correct errors on the spot. Stress energy and material conservation.
✓ 2. Battery and Magneto Ignition Systems	30 (24/6) Day 18,19, & 20,21	Column 1 Reference — STS Reference 2a — 14a 2b — 3, 4d, 9, 14b 2c — 3, 4d, 9, 14c
a. Without references, identify basic facts and terms related to the principles of operation and the function and relationship of battery and magneto ignition system and components with 70% accuracy.	(12)	Instructional Materials 3ABR47330-SG-302, Battery and Magneto Ignition Systems 3ABR47330-WB-302, Battery and Magneto Ignition Systems 3ABR47330-SG/WB-302A, Battery and Magneto Ignition Systems 3ABR47330-PT-302B, Magneto Construction, Operation, Inspection, and Maintenance TO 33D6-3-4-1
b. Provided with technical publications, bench items, tools, and equipment, and following all safety precautions, repair or service ignition system components IAW technical publications.	(4)	Audio Visual Aids Delco-Remy Chart, Section D, Ignition Systems Charts - Battery and Ignition Systems Films: TF 1-4720, Principles of Automotive Magnetos TF 1-4676, Ignition System Spark Plugs TVL 47-14, Automotive Ignition Systems Transparencies, Ignition Systems
c. Supplied with engine trainer, tools, equipment, and technical publications, practicing personnel and equipment shop safety, use visual, auditory, operational means, and test equipment to check ignition systems IAW technical publications.	(8)	Slides [illegible] 4710 High Energy Ignition Training Equipment Trainers: 60-2527, Dwell Angle (10)

PLAN OF INSTRUCTION NO. 3ABR47330	DATE 2 January 1975	BLOCK NO. III	PAGE NO. 14

FORM 337A MAR 73 PREVIOUS EDITIONS OBSOLETE. ☆ U.S. GPO: 1973—779-403/129 (Fin[illegible] 84% - 8 X 10½) (Final reduction to include area above this line)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		60-2710, Engine, Ford, 6 Cyl (2) 60-2759, Engine Assembly, IHC 6 Cyl (2) 60-2761m, Engine, GMC 6 Cyl (2) 61-2800, Engine, Valiant 6 Cyl (2) 92902 Engine, Briggs & Stratton (2) Mechanic's Common Handtools (1) Special Tools (1) Bench Items: Ignition System Components (1) Universal Diagnosis Tester (2) Tach-Dwell Tester (2) Volt-Amp Tester (2) Timing Light (2) Oscilloscope (2) Spark Plug Cleaner (5) Spring Tension Gauge (5) Trainer: 59-2427, Mag Prin (10) Training Methods Discussion/Demonstration (12 hrs) Performance (12 hrs) Outside Assignment (6 hrs) Instructional Environment/Design Classroom (12 hrs) Laboratory (12 hrs) Instructional Guidance Discuss principles, operation, service, repair, testing, and troubleshooting of ignition systems. Complete training objectives using workbook, study references, test equipment, and safety precautions. Use PT for outside assignment.

PLAN OF INSTRUCTION NO. 3ABR47330	DATE 2 January 1975	BLOCK NO. III	PAGE NO. 15

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
3. Cranking Motors and Starting System a. Without references, identify basic facts and terms related to the principles of operation, function, and relationship of starting system components with 70% accuracy. b. Supplied with TO, bench items, tools, and equipment, and practicing all safety precautions, repair or service system components IAW technical publications. c. Provided with engine trainer, tools, equipment, and TO, and practicing all safety precautions, use visual, auditory, operational means, and test equipment to check starting systems IAW TO.	8 (6/2) Day 22	Column 1 Reference — STS Reference 3a — 12a 3b — 4d, 9, 12b 3c — 3, 4d, 9, 12c **Instructional Materials** 3ABR47330-SG-303, Cranking Motors and Starting System 3ABR47330-WB-303, Cranking Motors and Starting System TO 33D6-3-4-1 **Audio Visual Aids** Delco-Remy Chart, Section C, Cranking Motors Transparencies, Starting Systems **Training Equipment** Trainers: 60-2710, Engine, Ford, 6 Cyl (2) 60-2759, Engine Assembly, IHC 6 Cyl (2) 60-2761, Engine, GMC 6 Cyl (2) 61-2800, Engine, Valiant 6 Cyl (2) Mechanic's Common Handtools (1) Special Tools (1) Bench Item: Starter Assemblies (1) Armature Testers (5) Battery-Starter Tester (2) **Training Methods** Discussion/Demonstration (3.5 hrs) Performance (2.5 hrs) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (3.5 hrs) Laboratory (2.5 hrs) **Instructional Guidance** Discuss cranking motors, solenoids, magnetic switches, drives and starting circuits. Complete training objectives using workbook, test equipment, and study references.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS) 2	3 SUPPORT MATERIALS AND GUIDANCE
4. DC Charging System a. Without references, identify basic facts and terms related to the principles of operation, function, and relationship of DC charging system components with 70% accuracy. b. Supplied with bench items, tools, equipment, and TO, and using all safety precautions, check DC charging system components IAW TO.	3 Day 23	Column 1 Reference — STS Reference 4a — 13a 4b — 3, 4d, 9, 13b Instructional Materials 3ABR47330-SG-304, DC Charging Systems 3ABR47330-WB-304, DC Charging Systems TO 33D6-3-4-1 Audio Visual Aids Delco-Remy Chart, Sections E & F, Generators Charts - Cut-Out Relay [illegible] Films: TF 1-5174B, Automotive Electricity - Principles of Generators TF 1-5305, Automotive Electricity - Voltage Regulators Selected Transparencies [illegible] Training Equipment Trainers: 60-2710, Engine, Ford 6 Cyl (2) 60-2759, Engine Assembly, IHC 6 Cyl (2) 60-2761, Engine, GMC 6 Cyl (2) Mechanic's Common Handtools (1) Special Tools (1) Bench Items: A&B Circuit Generators (1) Regulator (1) Volt-Amp Tester (2) Tach-Dwell Tester (2) Armature Tester (5) Belt Tension Gauge (5) Training Methods Discussion/Demonstration (3 hrs) Instructional Environment/Design Classroom (3 hrs)

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)
✓ 5. AC Charging System	17.5 (13.5/4) Day 23,24, 25
a. Without references, identify basic facts and terms related to the principles of operation, function, and relationship of AC charging system components with 70% accuracy.	(6.5)
b. Supplied with bench items, tools, equipment, and workbook, and practicing all safety precautions, repair or service AC charging system components IAW workbook.	(2)
c. Provided with engine trainer, tools, equipment, and workbook, and practicing personnel and equipment shop safety, use visual, operational means, and test equipment to check DC and AC charging systems IAW workbook.	(5)

3 SUPPORT MATERIALS AND GUIDANCE

Instructional Guidance
Discuss principles, operation, service, repair, testing, and troubleshooting DC charging system components. Complete training objectives using workbook, test equipment, study references, and following safety procedures.

Column 1 Reference	STS Reference
5a	13a
5b	3, 4d, 9, 13b
5c	3, 4d, 9, 13c

Instructional Materials
3ABR47330-SG-305, AC Charging System
3ABR47330-WB-305, AC Charging System
3ABR47330-WB-305A, Alternator and Regulator Testing

Audio Visual Aids
Delco-Remy Chart, Section K, Fundamentals of Delcotrons
Delco-Remy Chart, Section M, Delcotrons and the Charging Circuit
Commercial Slides - Chrysler Alternator Principles
Chart - Rectifiers

Training Equipment
Trainers:
  60-2759, Engine Assembly, IHC 6 Cyl (2)
  61-2800, Engine Assembly, Valiant 6 Cyl (2)
Mechanic's Common Handtools (1)
Special Tools (1)
Bench Items:
  Alternator (1)
  Regulator (1)
Diode Tester (10)
Tach-Dwell Tester (2)
Volt-Amp Tester (2)
Belt Tension Gauge (5)

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Training Methods Discussion/Demonstration (6.5 hrs) Performance (7 hrs) Outside Assignment (4 hrs) Instructional Environment/Design Classroom (6.5 hrs) Laboratory (7 hrs) Instructional Guidance Discuss principles, operation, service, repair, testing, and troubleshooting AC charging systems and components. Complete the training objectives using the workbook, test equipment, and study references.
Related Training (identified in course chart).	4	
6. Measurement Test and Test Critique	1.5	

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TWSTI /30 Jan 75/ Exam	INSTRUCTOR 8-10
COURSE NUMBER 3ABR47330	COURSE TITLE General Purpose Vehicle Repairman, Part I
BLOCK NUMBER III	BLOCK TITLE Auto Electrical Units

LESSON TITLE
Battery and Magneto Ignition Systems

LESSON DURATION

CLASSROOM/Laboratory D&D 12 hrs/Perf 12 hrs	~~LABORATORY~~/Complementary 6 hrs	TOTAL 30 hrs

POI REFERENCE

PAGE NUMBER 14	PAGE DATE 2 January 1975	PARAGRAPH 2

STS/CTS REFERENCE

NUMBER STS473X0	DATE 3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. UDT 2. Trainer: 60-2527 3. Trainer: 60-2759 4. Trainer: 60-2761 5. Trainer: 61-2800 6. Trainer: 92902 7. Trainer: 60-2710 8. Trainer: 59-2427	None	None	1. 3ABR47330-SG-302 2. 3ABR47330-WB-302 3. 3ABR47330-SG/WB-302A 4. 3ABR47330-PT-302B 5. TO: 33D6-3-4-1 6. Film: TFI-4676 7. Film: TFI-4720

(OVER) **CRITERION OBJECTIVES AND TEACHING STEPS** (OVER)

a. Without references, identify basic facts and terms related to the principles of operation and the function and relationship of battery and magneto ignition system and components with 70% accuracy.

b. Provided with technical publications, bench items, tools, and equipment, and following all safety precautions, repair or service ignition system components IAW technical publications.

c. Supplied with engine trainer, tools, equipment, and technical publications, practicing personnel and equipment shop safety, use visual, auditory, operational means, and test equipment to check ignition systems IAW technical publications.

Teaching Steps are Listed in Part II.

☆ GPO: 1972 779-396/23

EQUIPMENT LOCATED
IN LABORATORY

9. Mechanic's Common Hand tools
10. Special tools
11. Ignition System Components
12. Tach-Dwell Tester
13. Timing Light
14. Volt-Amp Tester
15. Oscilloscope
16. Spark Plug Cleaner
17. Spring Tension Gauge

GRAPHIC AIDS AND
UNCLASSIFIED MAT.

8. Film: TVL47-14
9. Chart: Sec D Delco Remy
10. " CAFB74-121
11. " CAFB64-416
12. " CAFB64-417
13. " CAFB64-418
14. Transparencies: CT72-721 thru 726
15. CT72-728 thru 729
16. CT72-731 thru 732
17. CT72-734 thru 751

INDTRODUCTION

0 Hrs 30 Min

1. Attention and Motivation: Be sure that the students are mentally and physically alert and attentive by stating that the ignition system is the most critical sytem of a gasoline engine. Stress the importance of the ignition system. For performance and economy, it must be properly adjusted to operate at all speeds and throttle settings.

2. Review: Give the quiz on automotive batteries, grade and critique. Collect students homework assignments, grade and review. Review fundamentals and batteries as applicable to the ignition system.

3. Overview: Explain todays lesson and what is expected of each student. They will learn about the components, construction and basic operating principles of the ignition system and the inspection, repair, replacement and/or adjustment of components.

BODY

23 Hrs 10 Min

PRESENTATION:

1. Reference Para A, Part 1	Fundamentals of Automotive electricity.
a. Purpose of Ignition System	
(1) Deliver spark of sufficient intensity to ignite the air/fuel mixture in the combustion chamber at the right time.	CT72-737 the ignition system (Resistor by-pass type) CT72-729 Ignition system operation.
b. Sources of electrical energy	
(1) Battery (chemical)	Fundamentals of automotive electricity
(2) Generator (mechanical)	
c. Circuits in ignition system	Use charts to show battery ignition system, name components of each circuit.
(1) Primary (low voltage)	
(2) Secondary (high voltage)	Delco Charts, section "D"
d. Components of primary circuit	
(1) Ignition switch	
(a) Manually opens and closes the primary circuit.	

(2) Ignition Resistor	
(a) Purpose is to protect the primary coil windings and ignition points from high current	
(b) Ballast resistor-heat sensitive, by-passed during cranking-GM, Ford, Chrysler	May or may not be by-passed
(c) Non ballast resistor-not heat sensitive, not by-passed during cranking-Chrysler, pre 1966	May ar may not be by-passed
(d) Resistor wire-use in place of ballast resistor	Heat increases resistance
(3) Ignition Coil	Summarize here
(a) Purpose is to create high voltage through electromagnetic induction.	
1 Required voltage	CT72-736 Comparison of available and required secondary voltage What is needed to fire plug
2 Available voltage	What the coil can produce
(b) Construction	NOTE: Use trainer coils
1 Two sets of coil windings (primary and secondary)	CT72-721 Ignition coil construction Do not connect coil backwards. Will lose up to 40% of coil efficiency
2 Laminated soft iron core	
3 Filled with oil to dissipate heat and keep out moisture	CT72-722 Coil polarity Show chart CAFB 64-418
(4) Condensor	NOTE: Use trainer condensors

(a) Purpose	CT72-723 Condensor construction
1 Reduces arcing of the points	CT72-724 Condensor action
2 Aids in the collapse of magnetic field	Summarize here
(b) Connected in paralelle with the ignition points	
(5) Ignition points	CT72-725 Capacity and pitting
(a) Located in distributer	
(b) Mechanically makes and breaks the primary circuit	Closed by spring tension
(c) Builds and collapses magnetic field in ignition coil	
(d) Opened by lobes on distributer shaft	Use trainer 60/2527, ignition demonstrator, dwell angle
1 Degrees of dwell or cam angle is the amount of time the points are closed.	Use spring tension gauge
2 Degrees of dwell depends on size of point gap	Adjust dwell before adjusting timing.
3 Number of cam lobes corresponds to number of cylinders.	Summarize the primary circuit operation

END OF DAY SUMMARY

SUMMARY

1. Restate all objectives covered in todays lesson on construction and operation of the battery ignition system.	1. Restate objectives of the lesson (covered in this day)
2. Emphasize the importance of the ignition system for good vehicle performance and operation.	2. Emphasize the areas of major importance
	3. Use oral questions to determine areas to be retaught.

3. Use the following questions to determine the areas to be retaught.	Ask questions orally

a. What is meant by cam angle?

b. What will be the result of oil or dirt on the face of the contact points?

c. How are the points and condensor connected?

d. Explain how voltage is induced into the secondary circuit.

e. How and when is ignition point spring tension measured?

f. What is the purpose of the ignition resistor?

g. How do you prepare test equipment before using it?

h. Explain what required voltage and available voltage are?

ASSIGNMENT: CTT POI Para 2a-Part 2	2 Hrs
(1) Read student study guide 3ABR47330-302. Be prepared to answer questions on the ignition system tomorrow.	1. Identify study materials
(2) XXXXX Make a closing statement to tie lesson with assignment for next days lesson.	2. Give reasons for student to study assignment
(3) Remind students to set a pattern of study and then stick to it.	3. Mention method of study

INTRODUCTION TO NEW DAYS WORK

1. Arouse students interest by making a startling statement or asking a rhetorical question pertaining to basic ignition system components. Emphasize the importance of understanding the ignition system.

2. Review the main points of yesterdays lesson pertaining to the components of the battery, and the ignition system. Collect

students CTT homework, grade and review. Reteach as needed.

3. The objective for you today is to learn the components and operation of the secondary circuit. You will learn testing procedures for the ignition system and also the purpose, construction, servicing, and testing of spark plugs.

PRESENTATION:

1. Reference Para A, Part 2

    a. Components of secondary circuit — Use section "D" Delco charts

        (1) Secondary coil windings

        (2) Distributor cap

            (a) Constructed of bakelite or hard plastic — CT72-726 *Distributor cap and rotor construction

            (b) Works with rotar to' direct high voltage to proper spark plugs

            (c) Check for cracks, carbon tracks and corrosion of terminals

        (3) Rotor

            (a) Receives spark from coil and distributes to each sylinder

            (b) Check for cracks, carbon tracks and corrosion.

        (4) High tension wires

            (a) Heavy insulation because of high voltage

            (b) Steel filled wires

            (c) Carbon of resistor wires

                1 TVRS used to reduce

                XXXXXXXXXXXXXX

radio and television interference

2 Reduces spark plug electrode corrosion

Summarize the secondary circuit operation.

b. Distributer advance units

Show film TUL47-14 Auto electrical ignition systems

(1) Centrifugal or mechanical advance

(a) Advances timing to compensate for engine speed.

CT72-731D Distributer Assy. Centrifugal type mechanism.

(b) Moves distributor cam in the direction of distributor shaft rotation.

(2) Vacuum advance

CT72-732 Vacuum advance mechanism

(a) Advances timing to compensate for speed of combustion

(b) Move points opposite distributor shaft rotation

(c) Most effective at part throttle

(d) Amount of advance depends on;

Connected to carb or intake manifold

1 Throttle position

2 Resultant vacuum

(e) Used for economy purposes

Summarize advance mechanisms

2. Reference Para 2, Part 2

a. Ignition resistor

Use volts amp tester

(1) Voltage drop

(2) Connections

b. Ignition coil

(1) Coil heat

(2) Secondary continuity

(3) Capacity

c. Distributor

Use tach-dwell tester

- (1) Cap
- (2) Rotor
- (3) Points
- (4) Condensor
- (5) Distributor shaft
- (6) Advance mechanisms
- (7) Primary lead

d. Low and high tension wires

- (1) Visual inspection
- (2) Secondary efficiency
- (3) Primary wiring insulation

APPLICATION: Part b, Para 2

NOTE: Some of the application is interspersed throughout the presentation

1. Using bench items, such as distributors, coils, resistors, contact points, wiring and connections, common and special hand tools, T.O.'s, student workbook. Perform tasks related to the ignition system. Students will perform the the written assignment in the student workbook with help from the instructor, and will accomplish tasks IAW manufacturers specifications and technical orders.

Use 3ABR47330-WB-302
T.O. 3306-3-4-1
Hand tools
Special tools
Sun U.D.T.
Spring tension gauge

2. Students will draw a schematic of the battery ignition system using symbols and anme each item, and be able to explain its purpose without error.

3. XXXXXXXXXXXXXXXXXX -

3. Reference: Para C, Part 2	
a. Adjust ignition points (GM-6, Ford and Chrysler)	CT72-728 Distributor Assy. Use engine trainers: 60-2527, 60-2759 60-2761- 61-2800
(1) Remove distributer cap	SG 302
(2) Remove rotor	Battery and magneto
(3) Place point rubbing block on high point of cam lobe	Ignition systems
(4) Loosen hold-down screw	
(5) Adjust gap - Use feeler gauge	
(6) Tighten hold-down screw	
(7) Check with dwell meter	
b. Adjust ignition points (GM 6 cyl)	Use tach dwell
(1) Open window in distributor	Show how to use meter
(2) Insert 1/8" allen wrench	T.O. 3306-3-4-1
(3) Turn wrench to adjust points	
(4) Observe setting with dwell meter	
c. Basic Ignition timing	Demonstrate using tach dwell and timing light.
(1) Remove number 1 spark plug	
(2) Place number 1 piston on T.D.C. of compression stroke	Valve overlap or "thumb method"
(3) Install distributor in correct position as per manufacturer.	
(4) Position rotor in proper direction.	
(5) Find direction of rotor rotation	
(a) Turn rotor by hand	
(b) Check manufacturers specs.	

(6) Position distributer so the points are about to open	Static timing
(7) Install distributer cap	
(8) Replace secondary wiring	
(a) Place number 1 where rotor is pointing	
(b) Install remaining wires according to rotor rotation and engine firing order.	Use timing light Demonstrate Summarize procedures for adjusting points and timing engine
(9) Check with timing light	
4. Reference: Para C, Part 2	(Spark plug)
a. Purpose of spark plug	
(1) Provides an air gap to create a spark	
(2) Ignites air/fuel mixtuee in the cylinder	
b. Construction	Show chart CAFB 64-417
(1) Center electrode	CT72-735 Spark plugs (resistor type)
(2) Ground electrode	
(3) Shell (porcelain)	
(4) Gasket seat	
c. Types of plugs (heat ranges)	Show chart CAFB 64-416
(1) Hot	CT72-734 Spark plug heat range
(2) Cold	Show chart CAFB 64-415 extended electrodes
(3) Power tip	
d. Plug reach	

(1) Distance from gasket seat to end of threads

e. Thread size

(1) Diameter of threads measured in millimeters.

(2) Most common: 10, 14, 18 and 24 mm

f. Spark plug servicing

(1) Visual inspection

(2) Clean

(3) Sand blast (3 seconds only)

Use spark plug cleaning machine

(4) Square off electrodes

Show film Here

(5) Adjust gap

Show film TFI-4676
Ignition system (spark plug)
Summarize Spark plugs here.

(6) Test

APPLICATION:

1. Reference Para C, Part 2

T.O. 3306-3-4-1
NOTE: Some of the application is interspersed throughout the presentation

Use tach-dwell tester
Use volts amp tester

END OF DAYS SUMMARY

SUMMARY

1. Restate all objectives covered in todays lesson which are construction and operation of the secondary circuit testing procedure for the basic ignition system and the purpose, construction, servicing and testing of spark plugs.

Restate objective of the lesson (covered in this day)

2. Emphasize the importance of understanding the ignition system. The

Emphasize the areas of major importance

importance of a properly timed engine and of having spark plugs in good condition.	
3. Use the following questions (oral) to determine areas to be retaught.	Use oral questions to determine areas to be retaught.
a. What is the purpose of the condensor?	Ask questions orally
b. What is the purpose of the primary coil windings?	
c. What is point gap?	
d. How much voltage does a coil produce when under a load?	
e. What is used to measure point spring tension?	
f. What do you use to check the dwell of the contact points?	
g. What determines a hot or cold spark plug?	
h. What is plug reach?	
i. Describe the checks and reconditioning procedures for spark plugs.	
ASSIGNMENT: CTT POI Para 2A-2B	2 Hrs
1. Re-read student study guide 3ABR47330-302. Answer questions at the end of the chapter and give the page and paragraph where the answers were found. Read study material on on electronic ignition systems.	Identify study material
2. Make a closing statement to the tie in with the assignment for the next days lesson.	Give reasons for student to to study assignment
3. Mention the SQ3R method of studying and to study at the same time each day to form better study habits.	Mention method of study

INTRODUCTION TO NEW DAY's WORK

1. Gain the students attention by telling them the importance of understanding the electronic ignition system. Assure that the students are mentally and physically alert. Motivate the students toward successful completion of today's lesson by appealing to his need to know.

2. Review items of major importance in previous day's lesson. Collect, review CTT homework assignments. Reteach as needed. Give a brief, review of the ignition system as it pertains to todays lesson.

3. State todays objective by telling students how they are to learn construction, operating principles, testing and analyzing of the electronic ignition system.

PRESENTATION: ~~Refer~~

1. Reference Para A, Part 3

   a. Purpose of electronic ignition — Use Delco Charts

      (1) Same as conventional ignition system. Delivers a spark of sufficeint intensity to ignite the air fuel mixture in the combustion chamber at the right time.

      (2) Eliminates the ignition points

         (a) Eliminates dwell variance due to contact, point wear.

         (b) Elininates timing variance

         (c) Insures more efficeint engine operation and less maintenance.

   b. Electronic Ignition system components — Use bench items here:

      (1) Components which are the same as conventional ignition components. — Distributor control unit wiring

         (a) Distributor-housing

         (b) Advance mechanism

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- (c) Rotor
- (d) Distributor cap
- (e) Ignition coil (some)
- (f) Spark plugs

(2) New Components:

- (a) Dual ballast resistor
- (b) Pick-up unit
- (c) Reluctor
- (d) Control unit
- (e) Condensor no longer required.

(3) Construction and operation of electronic ignition:

- (a) Reluctor and pick-up physically. Replace ignition points and dist. cam. — Use transparancies CT
  - (1) Electromagnetic ~~dixm-~~ induction.
  - (2) Induced trigger signal
- (b) Electronic control unit
  - (1) Pick-up signal triggers control unit
  - (2) Control unit interupts primary current flow.
  - (3) Control unit electronically determines dwell (can not be changed)

4. APPLICATION

1. Para B, Part 3 — Use WS302B here Electronic ignition

Using engine trainers (slant 6) multimeter, common hand tools, T.O's and Commercial manuals and oscilloscopes, test, calibrate and set up engines per instructions on 3ABR47330-WS-3026

NOTE: Some application interspersed throughout this lesson
Engine Trainers:

END OF DAY SUMMARY

1. Restate all objectives covered in todays lesson which are construction, operating principles, testing and analyzing electronic ignition systems.

2. Emphasize the importance of understanding the difference between electronic ignition and conventional ignition systems.

3. Use the following questions as an oral quiz to establish areas to be reviewed or retaught.

    a. What are the six (6) items that are common to both ignition systems?

    b. What are the five new items that are peculiar to the electronic ignition system only?

    c. List the significant advantages of the electronic ignition system.

    d. What is a reluctor?

    e. Why do we use a non-metallic feeler gauge for adjustment?

INTRODUCTION TO NEW DAY'S WORK

1. Gain the students attention by telling them how useful and oscilloscope can be, if used properly. Ascertain that they are mentally and physically alert and attentive. Motivate the students toward successful completion of todays lesson by appealing to his need to know how to correctly use and interpret the wave forms of an oscilloscope.

2. Review items of major importance in previous days lesson. Collect ~~review~~ review CTT homework assignments. Reteach as needed.

Give a brief review of the ignition system as it pertains to todays lesson.

3. State todays objective by telling students how they are to learn the testing and analyzing of the ignition system using an oscilloscope. Also covered in todays lesson is the construction, and operation of the Magneto Ignition System.

PRESENTATION: Reference: Para C, Part 1

1. Participate in a discussion on the basic operation, and techniques for testing the battery ignition system using the Oscilloscope. Students will be able to answer questions with at least 70% accuracy.

    a. Purpose

        (1) Displays a graphlike picture of the voltage in an ignition system compared to time

        Use Sun Scope

            (a) Vertical line is voltage

            (b) Horizontal line is time

        (2) Useful in analyzing ignition system malfunctions

    b. Scope patterns (waveform)

    CT72-739 Basic Pattern Section

        (1) Primary waveform

        CT72-751 Primary Waveform Interpretation

            (a) Firing section

            Have students develop a typical waveform as pattern is discussed

                1 Period that the actual firing of the spark plug takes place

                Displays primary circuit
                CT72-741 Test Indications
                745 & 746 Test Indications

                2 Diminishing oscillations represent the repeated charging and discharging of the condenser while the plug is firing

                CT72-748 Test Indication

            (b) Intermediate section

                1 Gradually diminishing oscillations that represent the energy remaining in the coil

                CT72-740 Test Indication

after the spark is extinguished	CT72-747 Test Indications CT72-749 Test Indications CT72-750 Sun Scope Dwell Test
(c) Dwell section	
1 Begins when points close	
2 Shows time points remain closed	
3 Shows time current flows in primary circuit	Summarize here
(2) Secondary Waveform	Have students develop a typica waveform as the pattern is discussed
(a) Firing section	CT72-743 Test Indication
1 ~~ZTZZXZ44~~ Firing line	CT72-744 Test Indications
a Vertical line indicates voltage required to fire spark plug	
2 Spark line	Use Sun Scope and 64-3135 Auto A.C. & D.C. Systems
a Horizontal line indicates time plug firing	CT72-742 Test Indications
(b) Intermediate section	
1 Diminishing oscillations	
a Represent energy remaining in coil	
b Result of coil and condenser action	
(c) Dwell section	
1 Period of time points are closed	Summarize here

c. Calibration procedure

Use Sun scope and CP72-738 (A) Sun Scope Connections & Control

- (1) Connect scope to 110V source
- (2) Turn power switch to "ON"
    - (a) Pilot light shoudd be on
    - (b) Press reset button if not
- (3) Turn brightness control clockwise
- (4) Adjust parade and expand knobs to alighn with dots
- (5) Turn polarity switch to correspond to engine polarity
- (6) Rotate vertical position knob until dot moves across zero line
- (7) Adjust focus and brightness to obtain clear, sharp dot
- (8) Adjust parade knob until dot ends on right vertical line

Summarize here.

d. Scope connections to engine

Use Sun Scope

- (1) Secondary waveform pattern

For primary waveform connect pickup to distributor side of coil

    - (a) Red pattern pick-up lead to coil high tension lead
    - (b) Black pattern pick-up lead to ground
    - (c) Trigger pick-up lead to #1 spark plug wire
    - (d) Set polarity switch opposite vehicles battery
    - (e) Start engine and adjust idle speed

(f) Adjust firing line height to line 1 by rotating pattern height control knob

(g) Adjust xiggex trigger stability knob if waveform is unstable

(2) Superimposed waveform

(a) Connect xixxxx trigger pick-up lead to center of coil high tension wire

(b) Leave everything else as above

2. Reference: Para A, Part 1

The studentw will participate in a discussion on the basic operation and construction, procedures and techniques for servicing and testing the magneto ignition system by using bench item magnetos, coils, condensers, spark plugs, common and special hand tools, test equipment. Practice safety at all times and will be able to answer questions, written or oral, with at least 70% accuracy

a. Purpose of magneto

(1) To create electridty and to build voltage of sufficient intensity to ignite the air/fuel mixture in the combustions chamber at the right time.

b. Components

(1) Primary coil

(2) Secondary coil

(3) Contact points

(4) Condenser

(5) Distributor cap

Summarize here.

Use Trainer: Magneto principle 59/2427

Use Engine Trainers 92902 Engine Briggs & Stratton for demonstration

PT 3023 Magneto Construction Operation, Inspection and Maintenance
59-2427 Magneto Trainer

c. Operating principles

(1) Primary circuit

(a) Used to create a strong magnetic field

(b) Ground out primary to stop

(2) Secondary circuit

Summarize here

d. Advantages of magneto

(1) Very dependable

(2) Used in limited space

e. Disadvantages

(1) Weak spark at cranking speeds

(2) Hard to start

Impulse coupler

f. Common failures

(1) Contact points

(2) Faulty condenser

Show Film TF 1-4720L
Prin of operation of auto magneto

APPLICATION:

1. Para C, Part 4
Using such items as engine trainers, oscilloscopes, common and special hand tools, T.O.'s and commercial manuals. Students will calibrate and connect an oscilloscope to a live engine and perform tests as outlined in SG/WS 302A, using all safety factors with minimum guidance from the instructor.

Workbook 302B
Use Sun Scope & Engine Trainers 60-2759, 60-2761, 60-2800,
IHC GMC Valiant
60-2710-Ford

NOTE: Some of the application is interspersed throughout the presentation

Use hand tools and special tools
Timing Lights

2. Para C, Part 4

Use bench items, such as: Magnetos, spark plugs, common and special hand tools, T.O.'s and commercial manuals and test equipment, students will disassemble magnetos and inspect and adjust components. Complete student workbook 3ABR47330-302, using all safety factors with little guidance from the instructor.

Workbook 302B
Use engine trainers 92902
Engine Briggs & Stratton

T.O. 33D6-3-4-1 Commercial Manuals

EVALUATION:

1. What is the purpose of an oscilloscope?
2. How is time displayed on the scope?
3. How is voltage displayed?
4. What are the three sections of the primary waveform pattern?
5. What does the spark line of the secondary pattern show?
6. Explain what the dwell section shows?
7. Why are magnetos used?
8. What are some advantages of a magneto?
9. What are the disadvantages of a magneto?
10. Describe the operation of the magneto.

CONCLUSION 20 Min

SUMMARY AND REMOTIVATION:

1. Review all main points of todays lesson on using the oscilloscope and on the magneto ignition system.
2. Remotivate the students on knowing the proper procedures to use when using an oscilloscope and when repairing a magneto.

ASSIGNMENT AND CLOSURE: CTT POI Para 2C 2 Hrs

1. Review Student Study Guide 3ABR47330-302 and 3ABR47330-302B. Complete programmed instructional package on magnetos.

2. Prepare for a quiz tomorrow on battery and magneto ignition systems and the oscilloscope. Read SG-303, Cranking Motors and Delco booklet, the cranking circuit.

3. WRAP-UP: This concludes the subject but the information learned here will be applied as the student continues in the course. Review of this Study Guide and information is recommended throughout the course.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TWSTI / 28 Jan 75 Eiean	INSTRUCTOR
COURSE NUMBER 3ABR[redacted] 47232	COURSE TITLE Mechanic General Purpose Vehicle R[redacted]n, Part I
BLOCK NUMBER III	BLOCK TITLE Auto Electrical Units

LESSON TITLE
Cranking Motors and Starting System

LESSON DURATION

CLASSROOM/Laboratory D&D 3.5 hrs/Perf 2.5 hrs	XXXXXXXXX/Complementary 2 hrs	TOTAL 8 hrs

POI REFERENCE

PAGE NUMBER 16	PAGE DATE 2 January 1975	PARAGRAPH 3

STS/CTS REFERENCE

NUMBER STS473X0	DATE 3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 60-2710 2. Trainer: 60-2759 3. Trainer: 60-2761 4. Trainer: 61-2800 5. Mechanic's Common Hand Tools 6. Special Tools 7. Starter Assemblies	None	None	1. 3ABR47330-SG-303 2. 3ABR47330-WB-303 3. TO 33D6-3-4-1 4. Chart: Section "C" Delco Remy 5. Trans: CT72-780 6. Trans: CT72-793 7. Trans: CT72-794

(OVER) **CRITERION OBJECTIVES AND TEACHING STEPS** (OVER)

a. Without references identify basic facts and terms related to the principles of operation, function, and relationship of starting system components with 70% accuracy.

b. Supplied with TO, bench items, tools, and equipment, and practicing all safety precautions, repair or service systme components IAW technical publications.

c. Provided with engine trainer, tools, equipment, and TO, and practicing all safety precautions, use visual, auditory, operational means, and test equipment to check starting systems IAW TO.

Teaching Steps are Listed in Part II.

EQUIPMENT LOCATED IN LABORATORY

8. Armature Testers
9. Battery-Starter Tester

GRAPHIC AIDS AND UNCLASSIFIED MAT.

8. Trans CT 72-797
9. " " " 796
10. " " " 795
11. " " " 798
12. " " " 784
13. " " " 785
14. " " " 786
15. " " " 787

INTRODUCTION

0 Hrs 25 Min

1. Attention and Motivation: Gain the students' attention by asking them what it would be like to hand crank an engine to start it, such as was done in the days of the "Model "T" Ford". Motivate the students by asking them why we need a cranking motor? Explain the importance of the starting system.

2. Review: Give the quiz on ignition systems, grade and critique. Review fundamentals of electricity as applicable to today's lesson. Ask questions to be sure the students understand these basic principles

3. Overview: and TIE-IN: In today's lesson, we are going to learn the operating principles, construction, repairing and testing of cranking motors and starting systems.

BODY

5 Hrs 15 Min

PRESENTATION:

1. Reference Para a, Part 1 Students will participate in a discussion and determine the ~~purpose of~~ purpose of the starter system.	Use Student Study Guide SG303
a. Purpose of the cranking motor	CT72-780 The Starting Circuit
(1) Provide power for cranking internal combustion engines	
(2) Converts electrical energy into mechanical energy	
b. Caution	
(1) Starter undersize for capacity	Will be damaged if cranked to long
(a) Maximum safe operating time is 30 seconds	
(b) Wait 2 minutes before restarting	
2. Reference Para a, Part 1 Students will participate in a discussion on the operating principles of the DC cranking motor.	Use Bench Items: Cranking Motors & Armatures Battery-Starter Tester

a. Operating principles of the cranking motor	
(1) Current carrying conductor	Armature Field windings & pole pieces
(2) Magnetic field	
(3) Result (motion)	
(4) Direction of (motion) rotation	
(5) Commutator	
(a) Switches polarity of conductors	Summarize here.
3. Reference Para b, Part 1 Participate in a discussion on cranking motors	Use Bench Items: Starters Armature Testers
a. Components of cranking motor	CT72-793 Starting Motor Disassembled. Have students disassemble bench item starting motor Use Delco Remy charts Section "C"
(1) Armature (current carrying conductor)	
(2) Field coil and pole pieces	
(3) Housing or case	Aids magnetic circuit
(4) Commutator and end frame	
(5) Drive end housing and drive unit	
(6) Brushes	
(7) Thru bolts	Replace when half worn away
4. Reference Para f, Part 1	Use Bench Items: Starters Armature Tester
a. Cranking motor circuits	
(1) Two coil four pole	Battery Starter Tester
(2) Four coil four pole	
(3) Staight series winding	

(4) Series-shunt winding

(a) Purpose of shunt is to control over speeding of armature

Summarize here

5. Reference Para f, Part 1

a. Identify electrical malfunctions which can occur in starting motors

When soldering electrical connections, use Rosin Care Solder

(1) Open circuit

(2) Short circuit

(3) Unwanted ground

(4) Excessive resistance

b. Testing electrical components

Use armature tester (growler)

(1) Armature

(a) Opens

(b) Shorts

(c) Unwanted grounds

(2) Field windings

(a) Opens

(b) Unwanted grounds

6. Reference Para f, Part 1

Students will participate in a discussion and demonstration of the purpose and different types of starter drives.

a. Purpose of starter drives

(1) Transmits the cranking torque to the engine flywheel

(2) Disconnects the cranking motor from the engine flywheel when engine starts.

b. Types of starter drives	CT72-794 Starting Motor Drive Bench Items Starter Assembly Show students one of each type of starter drive
(1) Overrunning clutch	
(a) Operated manually or by a solenoid	Must have a shift lever Most common
(b) Positive action clutch	
(2) Bendix drive	"Automatic"
(a) Inertia operated	
(b) Drive spring acts as a shock absorber	Weak part of unit
	Summarize here
7. Reference Para f, Part 1 The students will participate in a discussion on the operating principles of cranking motor solenoid circuits.	CT72-797 Relay and gear shifting Solenoid Switch Circuit
a. Cranking motor principles of circuits	
(1) Foot operated control	Bench Item: Starter Assembly
(2) Pedal shift or manual control	
(3) Solenoid shift unit	CT72-795 Solenoids
(a) Two sets of windings	
1 Pull-in	Large dia. windings
2 Hold-in	Small dia. windings
(b) Connected in parallel	CT72-798 Cranking Motor (Enclosed Shift Lever Type)
(c) Need a shifting lever	
(d) Used with overrunning clutch	

(4) Magnetic switch	CT72-796 Magnetic Switch Circuits
(a) Makes use of shorter Battery cables	Less Resistance used in Fords
(b) Used with Bendix Drive	Use Bench Items: Starter Assy.
8. Reference Para f, Part 1 Students will participate in a discussion and demonstration on procedures for proper periodic cranking motor maintenance.	Use Bench Items: Starter Assy. Armature Tester Battery-Starter Tester
a. Cranking motor maintenance	
(1) Every 5,000 miles check all cables and connections, should be tight and clean	Use workbook 3ABR47330-WB-303
(2) To prevent overheating, do not operate motor longer than 30 seconds	
(3) Check for thrown solder	Summarize here
9. Reference Para c, part 1 Students will participate in a discussion and demonstration on the established procedures, using test equipment to test cranking motors. Students will have a basic understanding of these tests.	Engine Trainers: 60-2710 Ford 6, 60-2759 IHC 6 Cyl, 60-2761 GMC 6 Cyl, and 61-2800 Valiant 6 Cyl. C172-784 Starter Motor Amperage Draw Test CT72-785 Free Running Amperage Draw Test CT72-786 Starter Insulated Circuit test CT72-787 Starter Ground Circuit Test
a. Testing cranking motors	Use battery-starter tester (Sun Y-20)
(1) Resistance Tests	Use ~~battery~~ Bench Items: Starter Assemblies
(2) Amperage draw test	Armatures

APPLICATION:

1. Reference Para c, Part 1	NOTE: Some of the application is interspersed throughout the the presentation.

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Use Trainer Engines:
60-2710 Ford 6 Cyl
60-2759 IHC 6 Cyl
60-2761 GMC 6 Cyl
61-2800 Valiant 6 Cyl
Hand Tools and Special Tools
Battery-Starter Tester

2. Reference Para C, Part 1
Using required test equipment and engine trainers, student will perform a check of the vehicle starting system. This will be done under the supervision of the instructor.

Use: T.O. 33D6-3-4-1
Commercial Manuals
Workbook 303
Use mechanics common hand tools

EVALUATION:

1. What is the purpose of the starting motor?
2. The cranking motor must never be used for more than how many seconds at any time?
3. What tests are performed on the armature using the growler?
4. What is the main difference between the bendix and overrunning clutch type starter drives?
5. The two windings of a solenoid are connected to operate in?
6. Explain the purpose of the pull-in and hold-in windings in a solenoid?

CONCLUSION 20 Min

SUMMARY AND REMOTIVATION:

1. Review the main points of today's lesson on the construction and operation of starting motors, starter drive units, solenoids and magnetic switches and testing the electrical components.
2. Remotivate the students about knowing how to service the cranking motor and the starting system.

ASSIGNMENT AND CLOSURE:

1. Read Student Study Guide 3ABR47330-303. Answer questions on this assignment and give the page and paragraph where the answer was found. Read Delco booklet - Regulation and the charging circuit.

2. Study methods: Using SQ3R method study and answer questions at the end of the chapter.

3. WRAP-UP: This concludes the subject, but the information learned here will be applied as the student continues in the course. Review of this material and information is recommended throughout the course.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TWST0 / 28 Jan 75	INSTRUCTOR
COURSE NUMBER 3ABR[redacted] 47232	COURSE TITLE General Purpose Vehicle [redacted] Mechanic, Part I
BLOCK NUMBER III	BLOCK TITLE Auto Electrical Units

LESSON TITLE
D.C. Charging System

LESSON DURATION

CLASSROOM/Laboratory D&D 3.0 hrs/Perf 0 hrs	~~xxxxxxxxxx~~/Complementary None	TOTAL 3 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
17	2 January 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 60-2710 2. " " 2759 3. " " 2761 4. Mechanic's Common Hand Tools 5. Special Tools 6. A&B Circuit Generators (OVER)	None	None	1. 3ABR47330-SG-304 2. 3ABR47330-WB-304 3. TO: 33D6-3-4-1 4. Film: TFI-5174B 5. " " 5305 6. Chart:CAFB74-123 7. " " " 124 8. " " " 122

CRITERION OBJECTIVES AND TEACHING STEPS (OVER)

a. Without references, identify basic facts and terms related to the principles of operation, function and relationship of DC charging system components with 70% accuracy.

b. Supplied with bench items, tools, equipment, and TO, and using all safety precautions, check DC charging system components IAW TO.

Teaching Steps are Listed in Part II.

ATC FORM AUG 72 770

☆ GPO: 1972 770-396/23

EQUIPMENT LOCATED
IN LABORATORY

7. Regulator
8. Volt-Amp Tester
9. Tach-Dwell Tester
10. Armature Tester
11. Belt Tension Gauge

GRAPHIC AIDS AND
UNCLASSIFIED MAT.

9. Chart: CAFB 68-80
10. " " 68-81
11. " "Delco Remy, Sec E
12. " "Delco Remy, Sec F
13. Trans: CT 72-754 thru 758
14. Trans: CT 72-760 thru 764
15. Trans: CT 72-766 thru 770

INTRODUCTION

0 Hrs 20 Min

1. Attention and Motivation: Ascertain that the students are both physically and mentally alert. Ask students how long a battery would last if it was not for the vehicle's charging system. Stress the importance of the charging system. Have the students relate some of their personal experiences they may have had on charging systems work.

2. Review: Give students the quiz on starting motors, grade and critique. Collect the written homework assignments, grade and review. Also review the principles of electromagnetic induction as they apply to today's lesson.

3. Overview: Today we are going to discuss the operation of the generator and generator regulator, the proper procedures for adjustment, repair and/or replacement of components, and the use of tools and equipment and safety procedures to be used when working on the D.C. chargine system.

BODY

2 Hrs 30 Min

PRESENTATION:

1. Reference Para a, part 1

Students will participate in a discussion of the units of the D.C. charging system and the "A" and "B" circuit generators and regulators	Charts: Use Section "E" of Delco Remy
a. Purpose of generator	
(1) To convert mechanical action into electrical energy	CT72-754 Generator Function
(2) To recharge the battery and to supply current to the automotive electrical systems	
b. How generator develops voltage	Demonstrate using a magnetic field, closed conductor, and motion
(1) Closed conductor (armature)	
(2) Magnetic field	Electromagnetic Induction
(3) Relative motion	

c. The simple generator	
(1) Field circuit	
(2) Charging or load circuit	
d. Construction of the D.C. generator	Have students disassemble bench item generators
(1) Armature	CT72-756 High Speed Generator
(2) Commutator and brushes	
(a) Mechanical rectifier	Replace brushes when half worn away
(b) Changes A.C. to D.C.	
(3) Field windings and pole pieces	
(a) Produce magnetic field	CT72-757 Air Cooling of Generators
(b) Residual magnetism	Summarize the construction of the generator. Compare to the starting motor
(4) Iron frame housing	
e. Two brush generator (shunt type)	Use chalkboard
(1) "A" circuit (standard duty)	CT72-763 Generator Circuits
(a) Shunted in the generator	
(b) Grounded at the regulator (externally)	
(c) Most commonly used	
(2) "B" circuit (heavy duty)	Ford uses "B" circuit CT72-763 Generator Circuit "B" Circuit
(a) Shunted in the regulator	
(b) Grounded in the generator (internally)	Show film TF 1-5174B

2. Reference Para A, Part 1	Principles of operation of the generator shunt type.
Students will participate in a discussion on the D.C. charging systems (generator)	
a. Basic electrical malfunctions	
(1) Shorts (increase current flow)	
(2) Opens (no current flow)	
(3) High resistance (decreased current flow)	
(4) Unwanted grounds	
b. Testing generator components	Give students demonstration with use of growler (armature tester)
(1) Armature	CT72-764 Tester Connections CT72-765 Tester Connections
(a) Opens	
(b) Shorts	CT72-755 Testing Generator
(c) Unwanted grounds	
(2) Field coils	Give students demonstration with use of battery and an ammeter
(a) High resistance	CT72-761
(b) Unwanted grounds	Charging System Resistance Tests
(c) Open circuits	
(d) Short circuits (field current draw)	
(3) Brushes and brush holders	
(a) All output passes through insulated brush	
(b) Replace when ½ worn away	
(c) Opens and unwanted grounds	Use test light
(4) Motoring the generator	Summarize bench testing

3. Reference Para A, Part 1

Students will participate in a discussion on the purpose for ploarizing and testing generator o output.

CT72-770 Generator Polarity

CAUTION: Generator of the wrong polarity will burn cut-out relay points.

a. Polarization of the Generator

  (1) "A" circuit

    (a) Disconnect field wire at regulator and connect to ground

CT72-768 Generator Polarity

    (b) Jumper wire from A to B terminal at regulator

CT72-769 Generator Polarity

  (2) "B" Circuit

    (a) Disconnect field wire at regulator and jump to battery terminal of regulator

-Done for testing purposes only

b. Testing generator output by-passing regulator

  (1) By-passing cutout relay ("A" and "B" circuits)

    (a) Jumper wire between battery and armature terminals

    (b) Engine must be running above idle

  (2) By-passing voltage and current regulators

    (a) "A" circuit

      1 Remove field wire at regulator and ground it

    (b) "B" circuit

      1 Jumper wire from armature to field terminal

Summarize here

4. Reference Para A, Part 1	Charts:
Students will participate in a discussion on how to locate and identify units of the generator regulator	Use Sec "F" - Regulators Pass around bench item regulators to all students
a. Purpose of generator regulator	
(1) Prevents excessive current and voltage	
(2) Protects the battery and accessories	
(3) Protects the generator	
b. Operating principles of the "A" and "B" circuit generator regulator	
(1) Three circuits of generator regulator	CT72-758 Circuit Breaker Action CT72-760 Current Regulator Action CT72-766 Charging circuit with double constant voltage reg.
(a) Charging	
(b) Field	
(c) Operating	
(2) Cutout relay	Show Charts CAFB " " "
(a) Pull to close electromagnetic switch which opens and closes the circuit between the battery and generator thus preventing the battery from discharging through the generator	" " "
(b) Closed by generator voltage	If stuck closed battery will discharge during low or stopped speeds

(c) Opened by reverse battery current and spring tension	
(3) Current regulator	Show Charts CAFB Current Regulator
(a) A pull to open electromagnetic switch which protects the generator from excessive output	
(b) All generator output passes thruthe current regulator windings	
(4) Voltage regulator	CEMF vibrating type 50 to 200 times per second
(a) A pull to open electromagnetic switch which prevents overcharging of the battery and protects the accessories from high voltage	Summarize purpose and operation of the regulator Show Chart CAFB Voltage Regulator
c. Limitation of vibrating points	
(1) Points will arc when opening	
(2) Six volt system has 2-amp flow in the field circuit, twelve volt system has 1.5 amp flow in field circuit	
(3) Regulator of wrong polarity will burn current and voltage regulator points	
5. Reference Para A, Part 1	
Students will participate in a discussion of generator regulators	Show film TF 1-5305 Principles of Operation of the Generator Regulator

a. Visual inspection

   (1) Point alignment and oxidation

   (2) Opens and grounded circuits

   (3) Frayed or loose connections

   (4) Corrosion on terminals

b. Electrical adjustments of regulators

   (1) Done on vehicle

   (2) To increase output, increase spring tension; to decrease output, decrease spring tension

   (3) Final reading made with cover in place

Use volts Amp tester (CB-12)

CT72-767 Standard Regulator

APPLICATION:

1. Reference Para B, Part 1

Students will disassemble, inspect, test, service and repair components of new or reconditioned bench items (generators and regulators) IAW work procedures outlined in student workbook 3ABR47330-304. Using common hand tools and necessary test equipment; this work will be done under close supervision of the instructor in the classroom. Students will gain a basic unerstanding of these procedures, and complete projects in workbook.

NOTE: Some of the application is interspersed throughout the presentation.
Engine Trainers
60-2710 Ford 6 Cyl
60-2759 IHC 6 Cyl
60-2761 GMC 6 Cyl

2. Reference Para B, Part 1

Students will reassemble bench item generator under the supervision of the instructor, stressing safety at all times.. The students will perform a generator motoring test.

EVALUATION:

1. Why is it necessary to polarize a generator?

Ask questions orally.

2. How is an "A" circuit generator polarized?
3. How is the voltage and current regulators by-passed on and "A" and "B" circuit system?
4. How is a "B" circuit generator polarized?
5. When should generator brushes be replaced?
6. What is used to clean a commutator?
7. Why do we motorize a generator?
8. What is the purpose of the gen~~xxx~~erator output test?
9. What tests are performed on the growler?
10. What operates the three units in the generator regulator?
11. What is the purpose of the:
    - (1) Cutout relay?
    - (2) Voltage regulator?
    - (3) Current regulator?
12. How do you change the output setting on the regulator?
13. How is initial generator output started?
14. What is the purpose of the D.C. charging system?

CONCLUSION 10 Min

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SUMMARY AND REMOTIVATION:

1. Highlight the main points on the purpose, construction and operation of the D.C. generator and the generator regulator.

2. Impress upon the students the importance of properly checking out the D.C. generator and charging system and the consequences for failing to do so.

ASSIGNMENT AND CLOSURE:

1. Read Student Study Guide 3ABR47330-304. Write out the answers to the questions at the end of the chapter and give the page and paragraph where the answer was found. Read Delco Booklet titled - Delcotron.

2. Study Methods: Using SQ3R Method study and answer questions at the end of the chapter.

3. Be prepared for a daily quiz on the D.C. charging system tomorrow morning.

4. WRAP-UP: This concludes the subject, but information learned here will be applied as the student continues in the course. Review of this material and information is recommended throughout the course.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TWSTI/ 28 Jan 75	INSTRUCTOR
COURSE NUMBER 3ABR47330	COURSE TITLE General Purpose Vehicle Repairman
BLOCK NUMBER III	BLOCK TITLE Auto Electrical Units - Part I

LESSON TITLE
A.C. Charging System

LESSON DURATION

CLASSROOM/Laboratory D&D 6.5 hrs/Perf 7 hrs	xxxxxxxxx/Complementary 4 hrs	TOTAL 17.5 hrs

POI REFERENCE

PAGE NUMBER 18	PAGE DATE 2 January 1975	PARAGRAPH 5

STS/CTS REFERENCE

NUMBER STS473X0	DATE 3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 60-2759 2. " 61-2800 3. Diode Tester 4. Mechanic's Common Hand Tools 5. Special Tools 6. Regulator 7. Alternators (OVER)	None	None	1. 3ABR47330-SG-305 2. 3ABR47330-WB-305 3. 3ABR47330-WB-305A 4. Chart: Delco-Remy, Sec K 5. Chart: Delco-Remy, Sec M 6. CC 73-153 (OVER)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without references, identify basic facts and terms related to the principles of operation, function and relationship of AC charging systems components with 70% accuracy.

b. Supplied with bench items, tools, equipment, and workbook, and practicing all safety precautions, repair or service AC charging system components IAW workbook.

c. Provided with engine trainer, tools, equipment, and workbook, and practicing personnel and equipment shop safety, use visual, operational means, and test equipment to check DC and AC charging systems IAW workbook.

Teaching Steps are Listed in Part II.

ATC FORM AUG 72 770

☆ GPO: 1972 779-396/23

EQUIPMENT LOCATED
IN LABORATORY

8. Tach-Dwell Tester
9. Volt-Amp Tester
10. Belt Tension Gauges

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7. Commercial Slid

INTRODUCTION

__ Hrs 20 Min

1. Attention and Motivation: Ascertain that the students are physically and mentally alert. Ask them if they have any experiences working on A.C. charging systems. Motivate them towards successful accomplishment of objectives by appealing to their need to know the diagnosing, testing, and repairing of A.C. charging circuits.

2. Review: Give a daily quiz on D.C. charging systems, grad and critique. Also review fundamentals of electricity. Impress upon the students the need to have an understanding of the fundamentals of electricity to understand alternators.

3. Overview: Give the students an overview of what will be covered, how it will be covered and what the student will be expected to learn about the construction, operation and testing of alternators and rectifiers.

BODY

12 Hrs 55 Min

PRESENTATION:

1. Reference Para a, Part 1

   Charts

   Participate in a discussion pertaining to alternators and rectifiers and will use applicable Air Force publications to locate desired information. Posseses and understands the basic principles and procedures related to nomenclature, facts, inspection, testing and repairing A.C. charging system units

   Use Section "M" & "K" Delco Remy
   NOTE: Some of the application is ~~interspersed throughout~~ interspersed throughout the presentation

   a. Output comparison (D.C. and A.C. generators)

      (1) Alternators produce sufficient current to carry normal load demands at idle speed

      Advantage

      (2) D.C. generator must reach cut-in speed before providing current to the load

      (3) Standard production alternator is designed to replace the standard production generator

b. Alternator charging system	Alternator Charging System
(1) Three main units	Have units available to show students
(a) Alternator	Bench Items
(b) Rectifier (diodes)	Alternators and regulators
(c) Regulator (voltage)	
c. Alternator main components	Disassemble alternator and point out each component
(1) Two end frames	
(a) Die cast aluminum	Bench Item Alternator
(b) Air vents	
(c) Bolted together with stator ('sandwiched" between them	
(2) Stator assembly	
(a) Stationary conductor	
(b) Laminated steel frame to reduce eddy currents	Eddy currents produce heat
(c) Three phase winding wound into slots	
(d) "Wye" connection (all three conductors joined at one end)	
(e) Manner in which the stator is wound and connected provides a self-limiting control of current	The overlapping of the stator windings eliminates the need for a current regulator
1 "Inductive reactance"	
2 Limits maximum current output	

(3) Rotor assembly	
(a) Rotating magnetic field	
1 Induces alternating current into the stator windings	
2 Externally excited by the vehicle's battery	
3 Strength of the magnetic field depends on amount of current flow through the field coil	Energized when ignition switch is turned on
(b) Pole pieces	
1 No residual magnetism	
2 One pole is always north and the other is always south	
(c) Ends of field coils are connected to slip rings	
(d) Brushes ride on slip rings	Provide connection between rotor and battery - Show bench item for comparison
(e) Field coil, pole pieces and slip rings are all pressed on shaft	
(f) Fans provide for cooling	Summarize here
d. Factors affecting alternator output	Same as a D.C. generator

(1) Speed of rotation of the rotor	
(2) Number of conductors in the stator	
(3) Strength of the magnetic field	
e. Rectification (internal or external)	In a D.C. generator A.C. was converted to D.C. through the brushes and commutator
(1) Changes A.C. To D.C.	
(2) Accomplished through the use of diodes	Demonstrate the working effects of a diode.
(a) A diode is a one-way check valve for the flow of electricity	Chanute Chart - Rectifiers
(b) Takes place of cut-out relay	
f. The rectification circuit	
(1) Diodes are connected between the stator windings and the battery	
(2) Three diodes are pressed into the heat sink (insulated)	
(3) Three diodes are pressed into the end frame (grounded)	Demonstrate methods of checking diodes
(4) Internal rectification	Use diode tester
(5) Full wave rectification through the use of diodes one + and one - for each stator winding	
g. Reversed battery polarity will produce:	Emphasize importance of correct battery polarity
(1) Direct short through diodes	
(2) Burned out diodes	

h. Effects of an open diode

Demonstrate use of diode tester

  (1) No current flow

  (2) Loss of current control at high rotor speeds

  (3) Slightly less than normal output at low speed

i. Effects of a shorted diode

  (1) Current flows both ways through a shorted diode

  (2) Approximately 50% loss of output

j. Diodes prevent reverse current flow from the battery

No need for a cut-out relay

  (1) Alternator battery wire is connected directly to the battery

    (a) Always impressed with battery voltage

  (2) Diodes prevent battery from discharging back through the alternator

Summarize here

APPLICATION:

1. Reference Para b, Part 1

Use WB-305

Using common hand tools, special alternator tools and diode tester, disassemble the alternator, make visual inspection, identify components, trace alternator internal circuits, test diodes for ipens and shorts, check stator windings for opens and xxxx grounds and reassemble the alternator. Perform all tasks with some guidance from instructor

NOTE: Some of the application is interspersed throughout the presentation

Bench Items: A.C. regulators and alternators

Diode tester

mainly on complicated steps of the operation.

END OF DAY SUMMARY

SUMMARY

1. Summarize the main points of today's lesson on the construction, operation, and testing of alternators and rectifiers (diodes).	1. Restate objectives of the lesson (covered in this day).
2. Remotivate the students on the importance of knowing how the alternator operates, so that they can properly check out the A.C. charging system.	2. Emphasize the area of major
3. Use the following oral questions to determine areas to be retaught.	3. Use oral questions to determine areas to be retaught.
a. What is the primary advantage of the alternator over the D.C. generator?	Ask questions orally.
b. What are some of the other advantages?	
c. What is the primary purpose of the diodes?	
d. How does the alternator provide control for maximum current output?	
e. Why is a cutout relay not required on an alternator?	
f. Why doesn't the rotor assembly have residual magnetism?	
g. What would happen if a battery was installed with reversed polarity in an A.C. system?	
h. At low speeds?	
i. Why does an open diode cause loss of current control at high alternator speed?	

j. How would a shorted diode affect alternator output?

ASSIGNMENT

1. Read Student Study Guide 3ABR47330-305. Answer the questions at the end of the chapter and give the page and paragraph where the answer was found.	1. Identify study materials.
2. Prepare for a daily quiz upon completion of tomorrow's lesson on the A.C. charging system.	2. Give reasons for student to study assignment.
3. WRAP-UP: This concludes the subject but the information learned here will be applied as the student continues in the course. Review of this study guide and information is recommended throughout the course.	3. Mention method of study.

INTRODUCTION TO NEW DAY'S WORK

1. Gain students' attention by asking them why it is necessary to have voltage in the A.C. charging system. Motivate them toward successful accomplishment of today's objectives by appealing to the need to know diagnosing, testing, repairing, and isolating A.C. charging system and circuits malfunctions.

2. Collect written homework assignment, grade and review. Review the operating principles of the A.C. charging system and have the students discuss alternator controlling factors as learned in yesterday's lesson.

3. Give an overview on the sequence of what will be covered in today's lesson on the voltage regulator, diagnosing charging circuit malfunctions, and testing the charging circuit.

BODY

PRESENTATION:

1. Reference Para C, Part 1

Participate in a discussion pertaining to the alternator regulator, the effects of	Bench Items:

battery CEMF in relation to alternator voltage and use of test equipment to locate and isolate A.C. charging system malfunctions. Students will possess an understanding of basic principles and procedures related to nomenclature, facts, inspection, testing and repairing A.C. charging system units to manufacturere's specifications.

A.C. regulators

a. Voltage regulator

Have regulator available to show students
Bench Items:
Regulators

(1) Limits maximum voltage output from the alternator

(2) Accomplished by controlling current flow to the field coil

Controls strength of magnetic field

(3) Regulator is connected in series with the battery and field coil

b. Field circuit (field current flow)

(1) Battery

(2) Ammeter

(3) Ignition switch

(4) Regulator

(5) Field terminal of alternator

(6) Field coil

(7) Ground back to battery

c. Regulator construction and circuits

Pass out Bench Items:
A.C. Regulators

(1) Ignition terminal

(2) Upper contacts

(3) Lower contacts

(4) Movable armature

(5) Voltage coil

(6) Resistors #1, 2 and 3

(7) Field terminal

(8) Fuse wires

d. Field current flow through upper contacts

Position of movable contact depends upon load demands

(1) Maximum field current flow

(2) Heavy load, low speed

(a) Low resistance in the circuit

e. Field current flow vibrating off upper contacts

(1) Increase in resistance in the charging circuit

(2) Limiting field current flow to the field coil

(a) Field current flow is through resistors 1 and 2 when moveable contact is not touching upper or lower contact point

f. Float position

(1) Alternator speed, load demands and battery demands are equal

(a) Field current flow is through resistors 1 and 2

g. Lower contacts

(1) Low load demands, high alternator speed

(a) Field current flow is through resistors 1 and 2 through lower contact to ground

h. Field current flow vibrating off lower contact

(1) Controlling maximum alternator output voltage

(a) Field current flow is through resistors 1 and 2 to field coil and through lower contact to ground

i. Diagnosing A.C. charging circuit malfunctions

Summarize here
Use Volt-Amp tester, also belt tension gauge

(1) Alternator output test

Engine Trainer 61-2800
Valiant 6 cyl. engine

(a) Determine alternator current output at a specified RPM

(2) Insulated circuit resistance test

(a) Measure voltage drop in insulted side of charging circuit

(3) Ground circuit resistance test

(a) Measure voltage drop in ground side of charging circuit

(4) Field circuit resistance test

(a) Measure voltage drop in the field circuit

(5) Voltage regulator test

(a) Determine voltage regulator setting

~~(b)~~

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(6) Voltage regulator adjustments	
(a) Spring tension	To increase setting, increase spring tension
APPLICATION:	
1. Reference Para C, Part 1	WB-305A
Using common hand tools, special alternator tools, publications, volts-amp tester, tach-dwell tester, engine trainer #61-2800 to test, isolate and adjust A.C. charging system malfunctions. Perform all tasks with some guidance and supervision mainly on the complicated steps of the operation. Also use belt tension gauge. All the above will be accomplished to manufacturer's specifications.	NOTE: Additional application of the D.C. charging system will be used during the application of the A.C. charging system, using concurrent training concepts. Use engine trainer 61-2800 Valiant engines. ALSO: Some of the application of the A.C. charging system is interspersed throughout the presentation. Compare Valiant trainer 61-2800 with IHC trainer 60-2759. Show use of belt tension gauge
EVALUATION:	
1. Explain field current flow starting at the battery.	Ask questions orally.
2. What is the purpose of the regulator?	
3. What causes the regulator moveable contact to pull from the upper to the lower contact?	
4. The voltage coil of the regulator is connected to the upper contact fuse wire. What type of circuit would this be?	
5. What adjustment would be made if the voltage regulator test on the upper contacts was below manufacturer's specifications?	

6. If the alternator current output test was below manufacturer's specifications what could be some of the causes?

7. Alternator output is at its maximum when the movable contact is in what position?

8. What would be the results if there was excessive resistance in the insulated circuit?

9. Why is it necessary to control voltage output while making the alternator output test?

10. When making the voltage regulator test, what must be taken into consideration in conjunction with the operating voltage?

CONCLUSION 15 Min

SUMMARY AND REMOTIVATION:

1. Summarize all the main points of today's lesson on the A.C. voltage regulator and A.C. charging system diagnosis and testing.

2. Remotivate the students on knowing the proper procedures to follow when checking out the A.C. charging system not only for good operation of the system but also to prevent damage to the diodes or regulator.

ASSIGNMENT AND CLOSURE:

1. Today is measurement! Review Student Study Guide, workbooks and class notes. Be sure to use a #1 or #2 lead pencil for the test.

2. WRAP-UP: This concludes the subject but the information learned here will be applied as the student continues in the course. Review of this Study Guide and information is recommended throughout the course.

PREPARE THE MAN

STUDY GUIDE 3ABR47330-SG-300

8-10

Technical Training

Mechanic
General Purpose Vehicle Repairman

BLOCK III
AUTO ELECTRIC UNITS

25 October 1972

CHANUTE TECHNICAL TRAINING CENTER (ATC)

Note: Copyrighted material is included on pages 28, 45, 49, 68, 136, and 149.

Supersedes SG 3ABR47330-301 through 305, 6 November 1968.
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The STUDY GUIDE AND WORKBOOK (SW) contains both SG and WB material under one cover. The two training publications may be combined when the WB is not designed for you to write in, or when both SG and WB are issued for you to keep.

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ELECTRICAL TERMINOLOGY, DEFINITION AND PURPOSE OF ELECTRICAL COMPONENTS

During the study of the following student study guides you will read and hear many electrical terms with which you may not be familiar. The following pages consist of electrical terms and their definitions. The definitions of these terms should aid you in understanding the subject being taught.

There are also terms and their definitions listed in the appropriate portion of the student study guide.

The definitions may differ somewhat from others which you have encountered. They are not intended to be all inclusive but have the purpose of serving as reminders so the student can quickly refresh his memory on electrical terms.

Electrical Terminology

Ammeter - An instrument used for the measurement of the rate of flow of electricity.

Ampere - A unit of measurement of flow of electrical current.

Arc - The travel of electricity through air between two electrodes which produces a flash.

Armature - The movable part of the electromagnetic device.

Battery - A unit (usually composed of lead plates and sulphuric acid and water electrolyte) which stores electrical energy in a chemical form.

Capacity or Capacitance - The property of a system of conductors and dielectrics which permits storage of electrical charges.

Coil - A circular arrangement of electrical conductors so that many conductors are placed side by side, to obtain the resultant effect of their combined magnetic fields.

Commutator - That portion of an armature, consisting of a series of copper segments which come in contact with the brushes.

Condenser - An accumulator of electrical energy.

Conductor - A continuous path along which electricity can flow.

Core - A metallic portion of a coil around which the conductors are wound.

Current - The quantity of flow of electricity.

Cycle - A complete act of recurrent values.

Dielectric - An insulating medium which intervenes between two conductors to prevent the flow of current from one conductor to another. Usually air, rubber, mica, glass, fiber or wood.

Electrode - The positive and negative terminal points of electricity, from which the electricity must travel through air or other substances.

EMF (Electromotive Force) - That force or pressure which causes current movement in an electrical circuit.

Farad - When a change of one volt per second across a condenser produces a current of one ampere, the condenser is said to have a capacitance of one "farad".

Field or Magnetic Field - That space which is affected by magnetic lines of force.

Frequency - The number of cycles completed in one second.

Generator - An electromagnetic device used to convert mechanical energy into electrical energy.

Ground or Grounded Circuit - A condition where the electrical circuit is connected or contacted with intentionally or unintentionally to the unit frame or framework.

Hydrometer - An instrument used for the measurement of the specific gravity of a liquid.

Induction or Inductance - That force which produces voltage when a conductor is passed through a magnetic field.

Magnet - That part which is known to possess magnetism.

Magnetism - That property possessed by certain substances (especially iron and steel) by virtue of which they can exert forces of attraction or repulsion, according to fixed laws. (It is the connecting link between electrical energy and mechanical energy).

Microfarad - Since the term farad is too large for any practical use, the term microfarad (one-millionth of a farad) is used.

Mutual Inductance - That property which causes an induced voltage to be set up in a second circuit, as the result of the change of current in the first circuit. (Example: secondary winding in an ignition coil or transformer.)

Ohm - A unit of measurement of resistance.

Ohmmeter - An instrument to measure resistance.

Ohm's Law - A law of electricity regarding the relationship between voltage, current and resistance. It takes a pressure of one volt to force one ampere of current through one ohm of resistance. Formula: Volts = amperes X ohms (E = I X R).

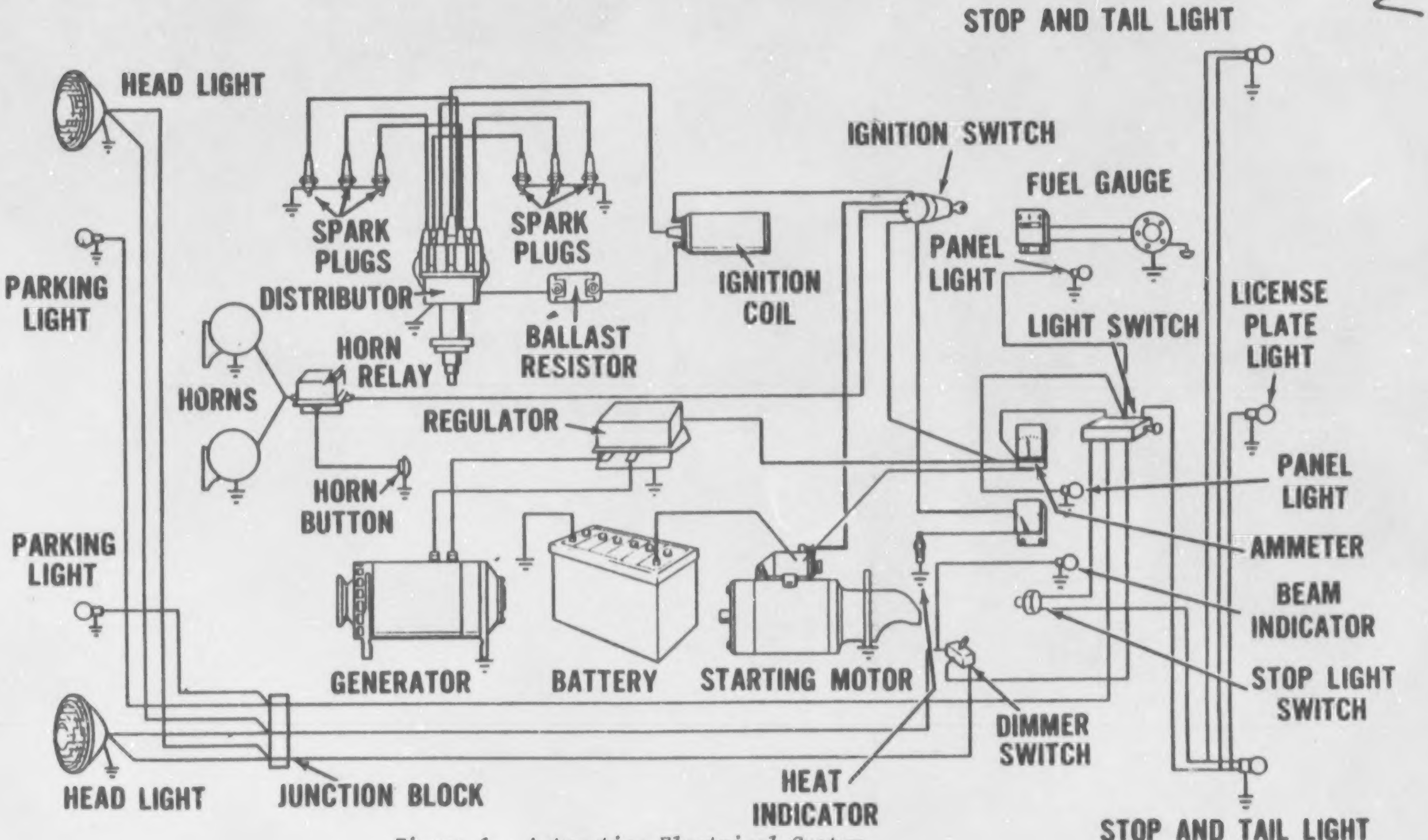
STOP AND TAIL LIGHT
HEAD LIGHT
IGNITION SWITCH
FUEL GAUGE
SPARK PLUGS
SPARK PLUGS
PANEL LIGHT
IGNITION COIL
DISTRIBUTOR
PARKING LIGHT
LICENSE PLATE LIGHT
LIGHT SWITCH
BALLAST RESISTOR
HORN RELAY
HORNS
REGULATOR
PANEL LIGHT
HORN BUTTON
AMMETER
PARKING LIGHT
BEAM INDICATOR
STOP LIGHT SWITCH
GENERATOR
BATTERY
STARTING MOTOR
DIMMER SWITCH
HEAD LIGHT
JUNCTION BLOCK
HEAT INDICATOR
STOP AND TAIL LIGHT

Figure 1. Automotive Electrical System.

Open Circuit - Any break or lack of contact in an electrical circuit, either intentional or unintentional.

Oscillation - A rapid back and forth movement.

Parallel Circuit - A circuit offering two or more paths for current flow.

Permanent Magnet - A part which retains the magnetic forces, even though the force which produced the magnetism is discontinued.

Resistance - That property of an electrical circuit which tends to prevent or reduce the flow of current.

Short Circuit - Generally an unintentional contact between two conductors, caused by faulty insulation or lack of insulation. This condition allows the current to bypass its normal circuit.

Starting Motor - An electromagnetic device, which can convert electrical energy into mechanical energy used for cranking the engine.

Volt - A unit of measurement of electrical pressure.

Voltage - That property of an electrical circuit causing current to flow.

Voltmeter - An instrument used to measure electrical pressure.

Watt - A unit of measurement of electrical power.
1 watt = 1 volt X 1 ampere. 1 kilowatt = 1,000 watts.

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-SG-301

FUNDAMENTALS OF AUTOMOTIVE ELECTRICITY, BATTERIES, AND BASIC ELECTRICAL CIRCUITS

OBJECTIVES

After completing this study guide and your classroom instruction, you will understand the basic principles of electricity and the construction, operation and servicing of automotive storage batteries, and be able to correctly construct the different types of electrical circuits and measure their voltage, amperage and resistance.

INTRODUCTION

Due to the amount of material to be covered in this lesson, this study guide will be separated into two sections. Section I will have the principles of electricity and magnetism, circuits, and the care and use of DC meters. Section II will cover the operation, construction and servicing of automotive storage batteries.

INFORMATION

Section 1. PRINCIPLES OF ELECTRICITY

A good automotive electrician must thoroughly understand the fundamentals of electricity. Because the electrician is working with something he cannot always see, he must have a good mental picture of the actions of electricity. With this knowledge, and a little common sense, the electrician will have no trouble understanding any electrical equipment when he finds it in the field. Figure 1 shows the complete automotive electrical system which the electrician must understand.

Man has known the practical use of electricity for over one hundred years. Rules about it have been learned during this time. However, no one knows just exactly what electricity is. Scientists have developed many theories about electricity. A theory is a statement which cannct be completely proved as true. These theories, however, explain better than anything else the behavior of electric current.

Electricity consists of the movement of electrons in a conductor. In order to understand what an electron is and how it behaves, let's look briefly at the composition of matter.

Composition of Matter

Matter is anything which has weight and occupies space. Therefore, matter is literally everything in the universe. Matter may be in the form of a solid, a liquid or a gas. Ice, water and steam are examples of matter in all three forms.

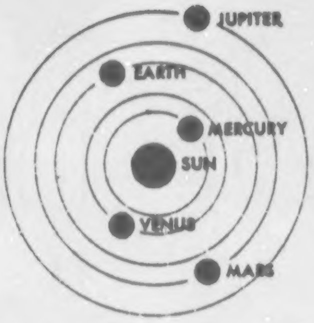
JUPITER
EARTH
MERCURY
SUN
VENUS
MARS

Figure 2. Solar System.

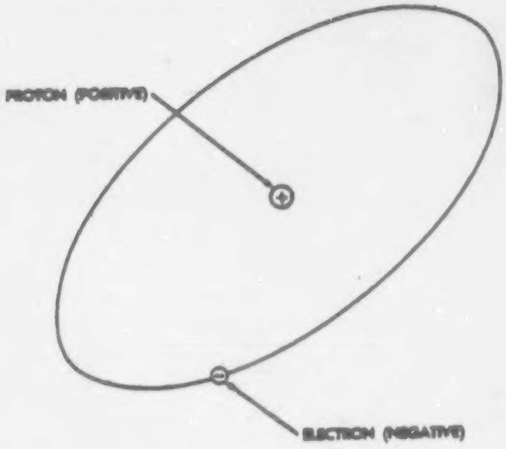
PROTON (POSITIVE)
ELECTRON (NEGATIVE)

Figure 3. A Hydrogen Atom.

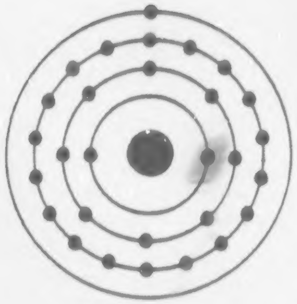

Figure 4. Copper Atom.

ELEMENTS. All matter is composed of building blocks called elements. Nature has provided 103 elements which combine in countless different combinations to form the various kinds of matter found on the Earth. Two of the more common and plentiful elements are hydrogen and oxygen. When these two elements are chemically combined, the result is water.

ATOMS. The smallest particle into which an element can be divided is the atom. An atom is so small that it cannot be seen even with the most powerful of microscopes. An atom is constructed much like our solar system, figure 2, in which the sun is the center or core and the planets revolve in orbits about the sun. In the atom, the center or core is composed of particles called protons, and the "planets" which revolve around the core are called electrons. An atom may also contain another particle called a neutron. If neutrons are present in the atom, they will be located in the core of the atom with the protons. To help us better understand the relationship between atoms and electricity, let's look at two different atoms — a hydrogen atom and a copper atom.

The Hydrogen Atom. A hydrogen atom is the simplest of all atoms known. It consists of one proton which has a small positive charge of electricity, and one electron which has a small charge of negative electricity. The electron moves in its orbit around the proton, figure 3. Negative and positive electrical charges attract each other. This attraction, however, is opposed by the tendency of the electron to fly away from the proton, a tendency resulting from its movement in a circular path around the proton. This is the same balancing force you get when a ball is attached to a rubber band and swung in a circle. As you swing the ball, the rubber band stretches because of the tendency of the ball to fly away from your hand. But the rubber band (the attractive force) keeps the ball moving in a circle around your hand.

The Copper Atom. A copper atom, figure 4, is much like the hydrogen atom except that it has 29 protons in its core. To keep the atom in electrical balance, an electron is added for each additional proton in the core. Note that these 29 electrons are in four separate orbits. The first orbit has two electrons, the next larger orbit has eight, the third eighteen, and the outer orbit only one. This outer electron is not very closely tied to the atom. A copper atom can lose this outer electron rather easily if a force is applied to it.

Theory of Electricity

It is not uncommon for some atoms to lose electrons when a disturing force is applied. With some disturbing force, there is a drift of electrons from one atom to another. When one atom loses an electron, it will pull another electron from a second atom in order to keep in balance. This second atom will give up its electron to the first atom, and at the same time collect an electron from a third atom, figure 5. This drift

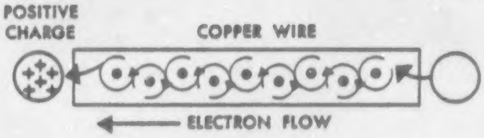

Figure 5. Electron Movement Through A Conductor.

of electrons from atom to atom is referred to as "a flow of current." The ability of atoms to do this is the theory of electric power. This continuous flow of electrons in an electrical circuit is called dynamic electricity, and leads us to this general definition: "Electricity is the flow of electrons from atom to atom in a conductor."

Current Flow

The flow of electrons through a conductor is called current, and is measured in amperes. When relatively few electrons flow in an electric circuit, the amperage or amperes of current is low. When many electrons flow, the amperage is high. The electric current is one ampere when 6.28 billion, billion electrons pass a certain point in a conductor in one second. Thus, current is the rate of electron flow and is measured in amperes or electrons per second.

FRANKLIN THEORY OF CURRENT FLOW. There are two means of describing current flow. The Franklin or Conventional Theory arbitrarily chose the direction of current flow to be from the positive terminal of a voltage source, through the external circuit, and then back to the negative terminal. This is the theory of current flow which we will use through this course, that current flow is from positive to negative.

ELECTRON THEORY OF CURRENT FLOW. The discovery of the electron in 1897 led to the electron theory of current flow, which is from the negative terminal, through the external circuit, and then back to the positive terminal -- just the opposite of the Franklin Theory!

WHAT IS DIRECT CURRENT? Direct current (DC) is electricity flowing one way continuously. Electricity used in the automobile for accessories and the ignition system is direct current.

AND ALTERNATING CURRENT? Alternating current, or AC for short, is current which reverses its direction of travel constantly. You've heard of 60-cycle alternating house current before. This is current which reverses its direction of travel 60 times per second.

Voltage

As said earlier, in order for electrons to flow from atom to atom, there must be some disturbing force applied to them.

This disturbing force which pushes electrons along a conductor is called electromotive force or voltage. Voltage is electrical pressure. A unit of measure for electrical pressure or voltage is called a volt. A high voltage means a high electrical pressure. Two sources of voltage in an automobile are the battery (a chemical source) and the generator (a mechanical source).

Resistance

Resistance is the opposition to current flow. Resistance can take many different forms or shapes and can be either wanted or unwanted. The unit of measurement for resistance is the ohm. An ohm is defined as the resistance that will allow one ampere to flow when there is one volt of pressure. This is an expression of Ohm's Law which will be discussed in a later topic. The symbol for an ohm is the Greek letter omega, and it looks like this: Ω

VOLTAGE DROP. Resistance uses up voltage in a circuit. All voltage must be used up. This is called voltage drop. Voltage drop in a circuit, when current is flowing, is always equal to the potential of the source. For example, a circuit is using a 12-volt battery as a source of voltage. There should be a 12-volt drop after passing through a light bulb. If the voltage drop is only 10-volts, the bulb will not burn as bright as it should.

Note: This law is very important for all mechanics to understand.

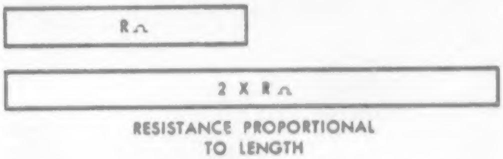

Figure 6. Resistance Affected by Length of Wire.

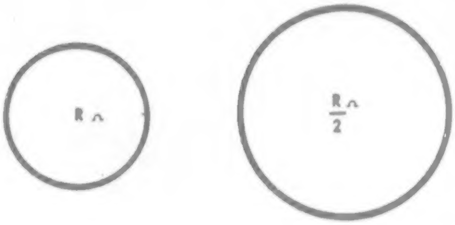

Figure 7. Resistance Affected by Diameter of Wire.

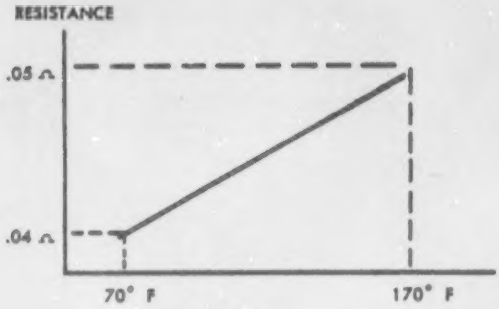

Figure 8. Resistance Affected by Temperature.

FACTORS OF RESISTANCE. There are many factors which will determine how effective resistance will be in a circuit. The major factors are the length, diameter and the temperature of the conductor or wire. If the length of the wire is doubled, the resistance between the wire ends is also doubled, figure 6. In other words, the longer the wire, the greater the resistance. If the diameter of the wire is doubled, the resistance for any given wire length will be cut in half, or, the bigger the wire in diameter, the less the resistance, figure 7. The other important factor affecting resistance of a wire is temperature. As the temperature increases, resistance increases, figure 8. The effects of temperature are very important in the design of electrical equipment. Excessive resistance from temperature increases can be very harmful to the performance of the equipment.

Conductors and Insulators

In order to put electricity to use as desired, some means must be provided for conveying electricity to its designated place without it taking a shortcut. This is accomplished by using conductors and insulators.

A CONDUCTOR GETS CURRENT THERE. Conductors are used as a means of conveying the electric current from one point to another. A good conductor is a material which offers very little resistance to current flow. Most metals are good conductors, and the more commonly used, in order of conductivity, are silver, copper and aluminum. Copper is the most commonly used conductor in automotive electrical circuits. It is used in the form of different sizes of wire. The size, or diameter, of a wire is called its gage. Also, since current must always return to its source, in automotive electricity one side of the circuit is grounded. This means that the body or frame of the vehicle is used to conduct the current in place of the wire. This eliminates half of the electrical wiring. Therefore, there is less of a chance for something to go wrong.

INSULATORS RESIST THE FLOW OF CURRENT. Whereas a conductor offers very little resistance to current flow, an insulator is any material that resists the flow of current. Examples of good insulators are mica, rubber, bakelite, fiber, porcelain, insulating varnish, and plastic. It should be kept in mind that an electric current will always take the path of least resistance and return to its source by the shortest distance available. Therefore, in an electric circuit, it is very important that the conductor be covered with some type of insulation so that the current must go to its source by following the path desired of it and not have any appreciable amount of electrical loss.

Characteristics of Electricity

Electricity is not visible. It can and does make itself known by one or more of the following effects however.

ELECTRICITY PRODUCES HEAT. When flowing through material of high resistance, current flow can produce heat. Many people today now heat their homes with electricity.

ELECTRICITY PROVIDES LIGHT. Current flow may also produce light when it flows through a material of high resistance. The electrical light bulb is a good example of this and the above also.

ELECTRICITY CAN SHOCK! Electric current flowing through a person's body produces this physical effect. To great of a shock may kill a person. On the other hand, shock has been used successfully by the medical profession for the treatment of heart patients and certain other ailments.

> Note: Don't be afraid of electricity for fear of shock. But treat it with respect. Generally its only the careless person that gets shocked.

ELECTRICITY PRODUCES A MAGNETIC FIELD. Current flowing through a conductor produces a magnetic field. Current flowing through a wire wound around an iron bar causes the bar to become magnetized, creating a North and South pole. The effects and importance of magnetism will be studied in later paragraphs.

OHM'S LAW AND ELECTRICAL CIRCUITS

The flow of current through an electrical circuit conforms to a very definite rule known as Ohm's Law. Ohm's Law expresses the relationship between current, voltage and resistance. Ohm's Law is one of the few rules which you must understand. In order to gain a working knowledge of how electric current will flow through the various branches of an electrical circuit, studying and solving problems using Ohm's Law will help. However, before studying Ohm's Law, it should be explained what a circuit is. In previous paragraphs, the word "circuit" has been used. No definition of this term has been given so far.

Electrical Circuits

As said before, the electrons in order to flow must have a path or circuit to move in. A circuit is a closed path for the flow of electricity. The starting point is the source of electrical pressure (voltage). The circuit is not complete until the conducting path has been traced back to the starting point where voltage began. Automotive electrical circuits may be classed as series, parallel, or series-parallel.

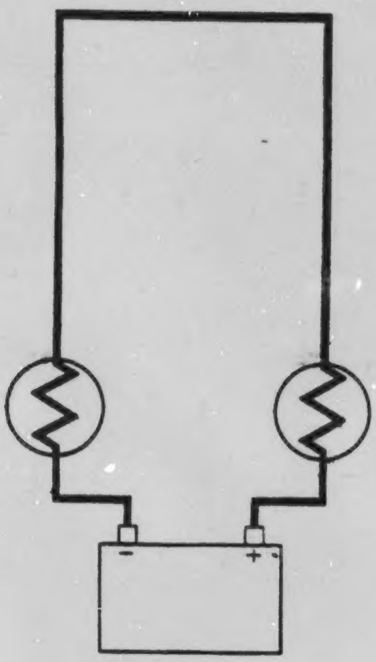

Figure 9. Series Circuit.

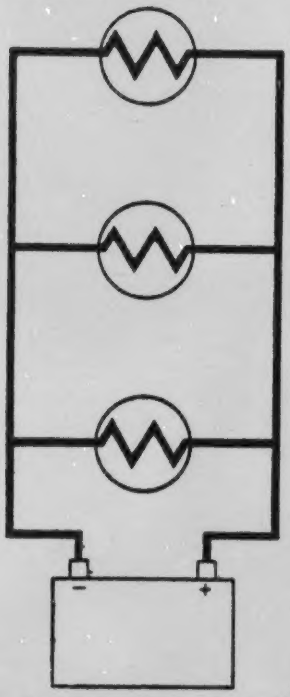

Figure 10. Parallel Circuit.

A SERIES CIRCUIT HAS ONLY ONE PATH. A series circuit is a circuit that has only one path in which current can flow. In a series circuit, figure 9, each electrical device is connected to other electrical devices so that the same current flows in all. If any device is turned off, then the circuit is opened and no current flows at all.

A PARALLEL CIRCUIT HAS TWO OR MORE PATHS. A parallel circuit is two or more paths for current to flow. In a parallel circuit, figure 10, the various devices are connected by parallel wires. The current devices, part of it flowing into one device, part into another. The same voltage is applied to each device, and each can be turned on or off independently of the others.

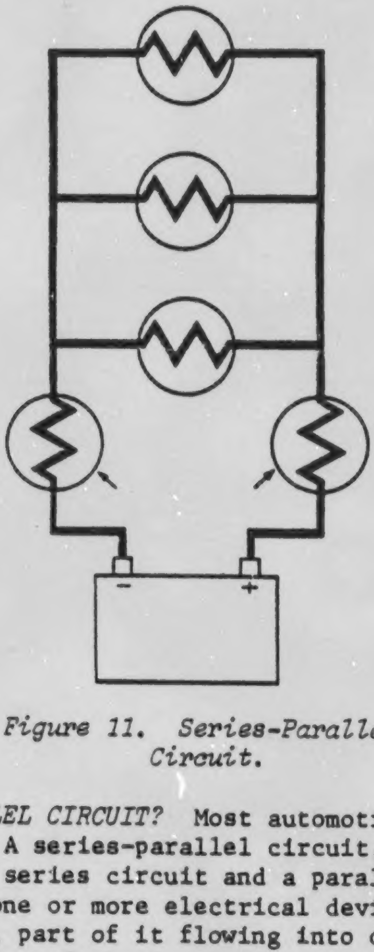

Figure 11. Series-Parallel Circuit.

AND A SERIES-PARALLEL CIRCUIT? Most automotive electrical circuits are of this type. A series-parallel circuit, figure 11, is a combination of a series circuit and a parallel circuit. Current will flow through one or more electrical devices in series and then divide itself, part of it flowing into one device and part into another. If any of the device is series, marked with an arrow in figure 11, are turned off or fail to operate, the circuit is opened and none of the other devices will operate either.

Ohm's Law

The above information gives us more of an idea what an electric circuit is and should aid in the understanding of the rule known as

Ohm's Law. Ohm's Law can be summed up as the relationship between current, voltage and resistance. It is named after the German scientist who discovered this relationship. Ohm's Law can be stated as follows: "It takes one volt to push one ampere through one ohm of resistance." It may also be stated in symbols, E = I X R, where:

E = pressure or voltage.
I = intensity or current.
R = resistance or ohms.

THE RULES OF OHM'S LAW. Ohm's Law can be expressed in three different ways, and can be applied to the entire circuit or to any part of a circuit. Let us remember these three simple rules which follow.

1. When voltage and amperage are known: volts ÷ amperage = resistance (R = E ÷ R).

2. When voltage and resistance are known: volts ÷ resistance = amperage (I = E ÷ R).

3. When resistance and amperage are known: resistance X amperage = voltage (E = I X R).

An easy way to remember these rules is to refer to the drawing in figure 12. By using the drawing, the formula for finding the unknown will be given by simply covering the unknown and doing the simple mathematical problem left showing.

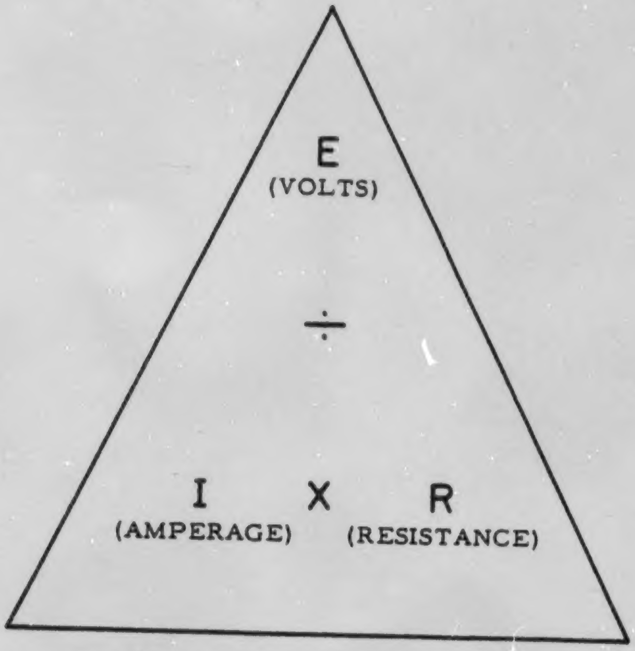

Figure 12. Formula for Finding the Unknown Value When Two Values Are Known.

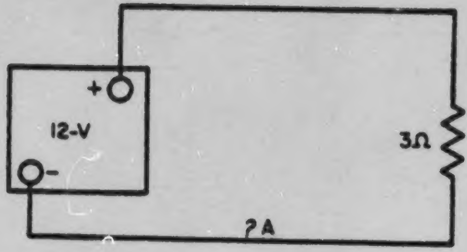

Figure 13. Simple Series Circuit for Using Ohm's Law.

APPLICATION OF OHM'S LAW. Let us work a simple problem to show how the above rules can be applied. A simple series circuit, figure 13, may consist of a three ohm (3Ω) resistor connected to a 12-volt battery. The current flow can be determined from Ohm's Law where I = E ÷ R, or, 12 volts ÷ 3 ohms = 4 amps. Current flow in this circuit then is 4 amps. Your instructor will give you some more problems to work using Ohm's Law.

MAGNETISM

Magnetism is a connecting link between mechanical energy and electricity. Without the effects of magnetism there could be no generators for charging batteries or motors for cranking engines. It was not until the year 1820 that the association between electricity and magnetism was discovered. Before this time it was generally believed that there was no relationship at all between electricity and magnetism.

Permanent Magnets

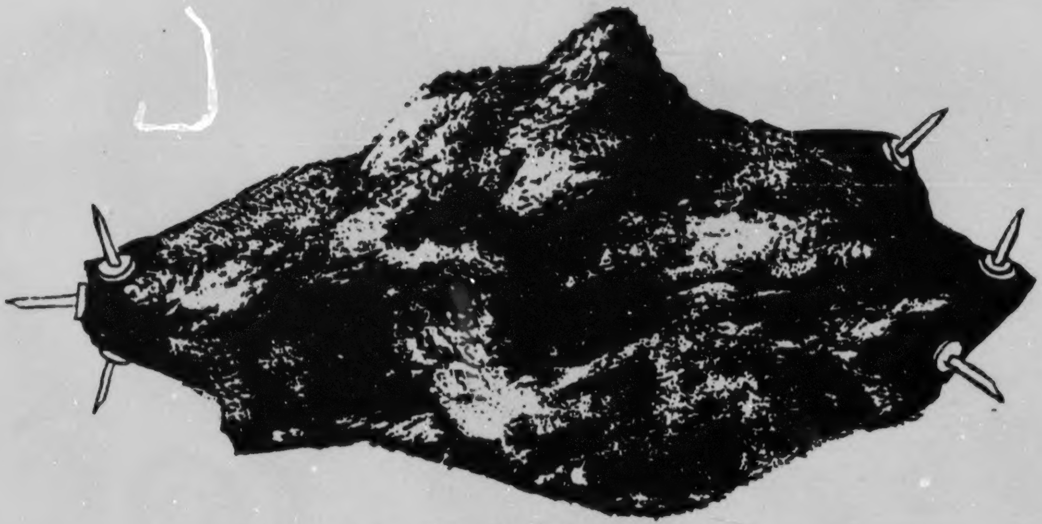

Figure 14. The Lodestone or Natural Magnet.

The effects of magnetism were first discovered when fragments of iron ore called lodestone, figure 14, which is found in nature, were seen to attract other pieces of iron. It was discovered that a long piece of iron ore, or an iron bar, hung in the air would align itself so that one end would always point toward the North pole of the earth. This end of the iron bar was called the North pole, or N pole. The other end was called the south pole or S pole. Such a piece of iron was called a bar magnet. Today, most permanent magnets are made of hard metals composed of alloys. Some of the more common alloys are nickel-iron and aluminum-nickel-cobalt, or "Alnico." Permanent magnets are found in many shapes, such as the well known horseshoe magnet.

The Magnetic Field

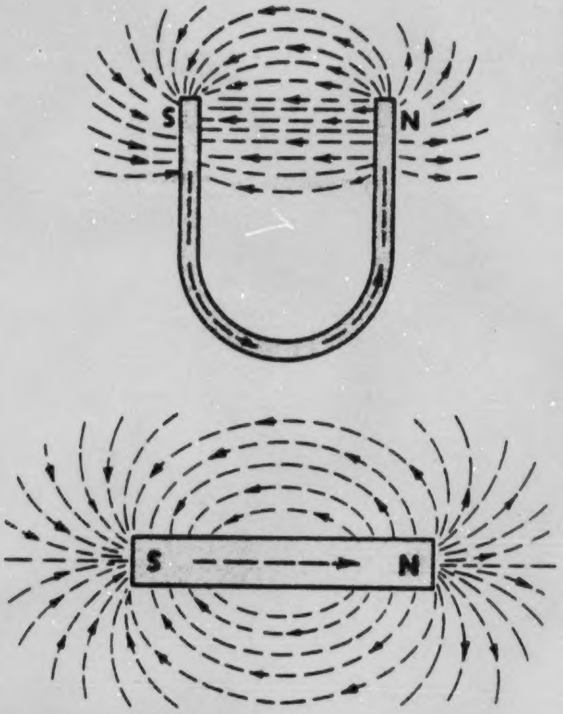

Figure 15. Magnetic Fields of a Bar and of a Horseshoe Magnet.

The space affected by a magnet is called the magnetic field. The magnetic field of a bar and horseshoe magnet are shown in figure 15. The magnetic field is described as "lines of force" which come out of the N pole and enter the S pole. There are no actual lines around the magnet, however. These lines of force are an easy way to show the invisible magnetic field. A good example of this is as follows: Take a bar magnet. Lay a piece of glass on top if it. Then, sprinkle iron filings on the glass. The filings become arranged in curved lines, figure 16. The curved lines of force extend from the two poles of the magnet and follow the magnetic lines surrounding the magnet. The extent of the field force is determined by the strength of the magnet. If the magnet is weak, there are relatively few lines of force. If the magnet is strong, there are many lines of force.

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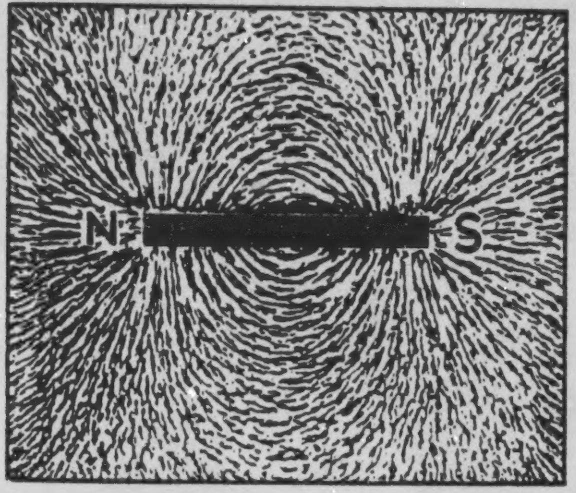

Figure 16. Magnetic Lines of Force of a Bar Magnet as Shown by Iron Filings.

CHARACTERISTICS OF LINES OF FORCE. To us, lines of force are invisible, unfelt, and imaginary. However, they are assumed to exist because they permit an easy explanation of the effects of magnetism. There are certain rules for these lines of force which may be summed up as follows.

1. Lines of force outside the magnet pass from the north pole to the south pole.

2. Lines of force act as rubber bands and try to shorten to a minimum length.

3. Lines of force repel each other along their entire length.

4. Lines of force never cross each other.

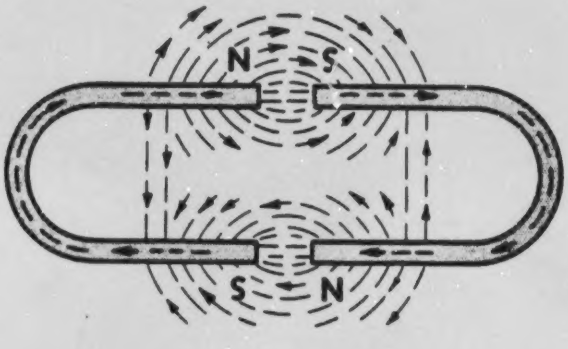

Figure 17. Unlike Poles Attract.

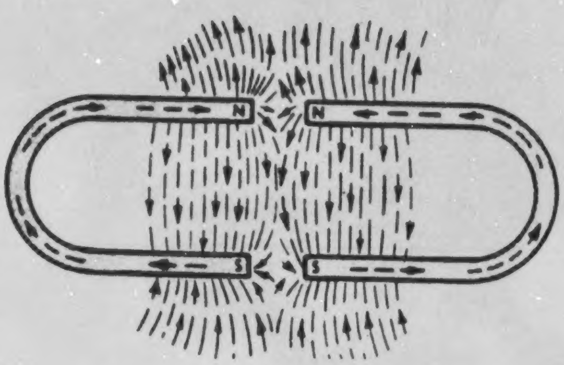

Figure 18. Like Poles Repel.

EFFECTS BETWEEN MAGNETIC POLES. When two unlike magnetic poles are brought together, they attract, figure 17. On the other hand, if the magnets are placed so that their like poles are together, they are found to repel each other, figure 18. From the above statement, this important fact about magnets can be stated: "Unlike magnetic poles attract each other and like magnetic poles repel."

MAGNETIC INSULATORS, ARE THERE ANY? Actually, there is no insulator for magnetism or lines of force. Magnetic lines of force seem to penetrate, or go through, all substances. They are deflected only by another magnetic field or magnetic material. The only "escape" or "insulator" from a magnetic field is distance or space.

Electromagnetism

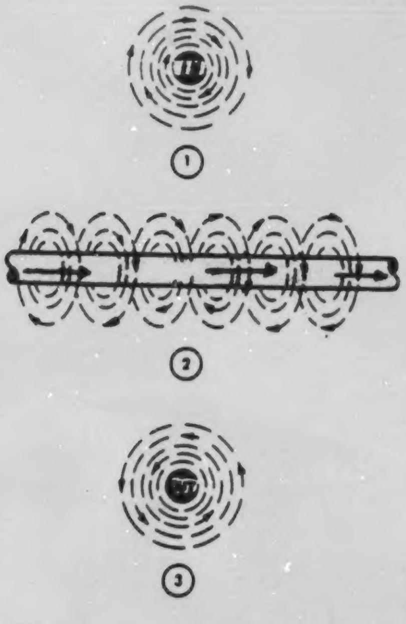

Figure 19. Magnetic Field Around a Wire Carrying Current.

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The discovery that an electric current always produces a magnetic field caused most of the development of modern electrical equipment. In a wire, current flow causes magnetic lines of force to circle the wire at right angles to the wire, figure 19. Unlike the flow of electrons in a conductor, which actually move, the magnetic lines of force do not move or flow around the wire. Instead, they merely have direction as indicated in figure 19. Fewer electrons in motion means a weaker magnetic field around the conductor. Therefore, the greater the current flow, the stronger the magnetic field.

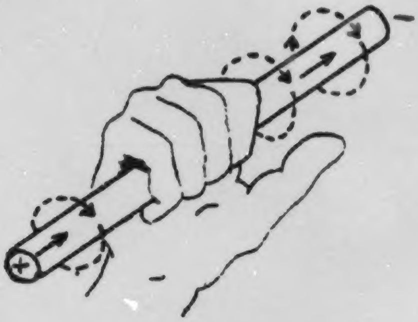

Figure 20. Determining Direction of Lines of Force - Right Hand Rule.

FINDING THE DIRECTION OF THE LINES OF FORCE. In order to find the direction of the lines of force around a conductor, there is a simple rule to follow. When using the Franklin theory of current flow (positive to negative), a simple rule known as the right-hand rule is used. Simply grasp the conductor with the right hand so that the thumb extends in the direction of the current flow, figure 20. The fingers will then point in the direction in which the lines of force surround the conductor.

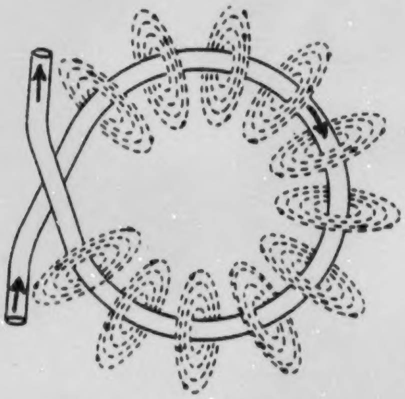

Figure 21. Magnetic Field in Loop of Wire-Carrying Current.

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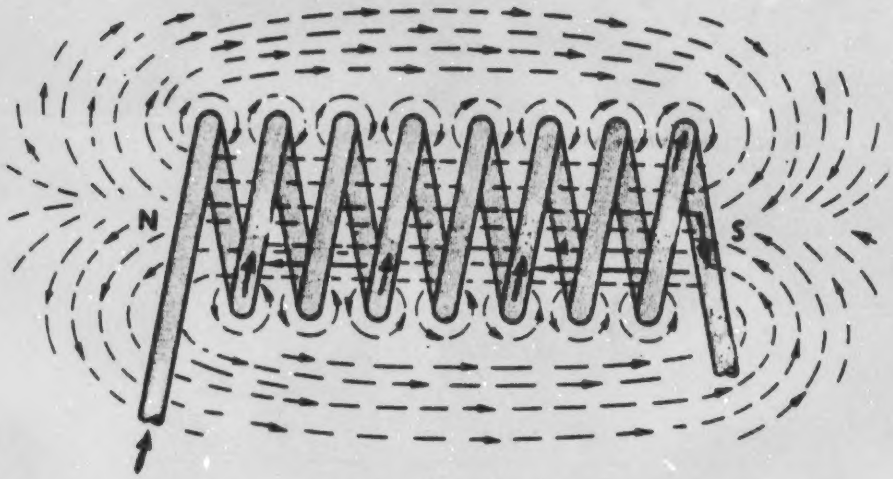

Figure 22. Magnetic Field Produced by Current Flowing in an Electromagnet (Loops of Wire Formed into a Coil).

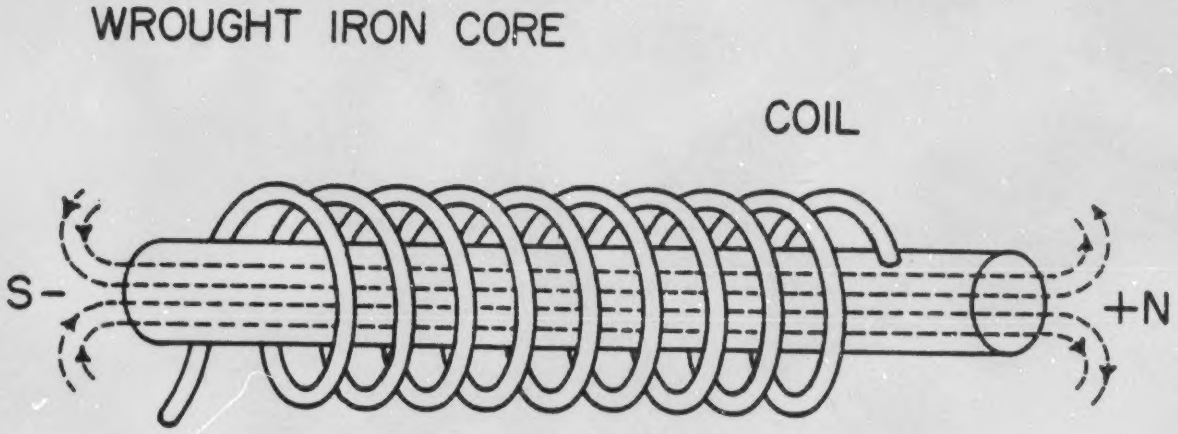

Figure 23. Coil With Wrought Iron Core Instead of Air Gap.

THE MAGNETIC FIELD IN LOOPS OF WIRE. On a straight wire conductor, the number of lines of force are greatest at the surface of the conductor and spread out into space as they expand away from the conductor. However, if a loop was formed into the wire, all of the lines of force around the conductor must pass through the inside of the loop, figure 21. The lines on the outside spread into space as they did on a straight conductor. The lines on the inside of the loop are contained. They increase the density of the number of lines of force in that area. If many loops of wire are formed, figure 22, it produces what is called a coil. The lines of force of all loops combine into a pattern that greatly resembles the magnetic field surrounding a bar magnet. This creates a much greater magnetic field with the same amount of current flow. It has also been found that more lines of force can be created by using a better conductor for lines of force than the original air gap in figure 22. It has been found that by placing an iron core into a coil, the strength of an electromagnet can be greatly increased, figure 23, as the lines of force now travel through the iron bar rather than through the air gap.

Strength of Electromagnets

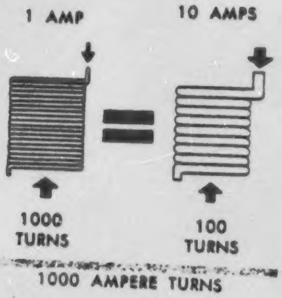

Figure 24. Ampere-Turn Comparison.

Electromagnets are constructed in various ways. Some are constructed to use large amounts of amperage (current). Starter fields and starter armatures are examples of this. Other applications are in relays, voltage regulators, etc., and are constructed to operate on very little amperage. The strength of an electromagnet is measured in "ampere-turns." Ampere-turns is the number of turns in the coil of wire times the amperage (current flow) through the windings. For example, 1 amp times 1,000 turns of wire equals 1,000 ampere-turns, as shown in figure 24. And 10 amps times 100 turns also equals 1,000 ampere-turns, shown in figure 24 also. Comparing the two electromagnets as shown, they have the same magnetic strength. The above facts must be kept in mind when working on electrical applications where electromagnets are used.

Electromagnetic Induction

In the year 1831, a very important discovery was made in the field of electricity when it was observed that a conductor moving across a magnetic field would have voltage or electromotive force (EMF) induced into it. This principle is called electromagnetic induction.

To illustrate this principle, consider a straight wire conductor that is moving across the magnetic field of a horseshoe magnet, as in figure 25. If a sensitive voltmeter were connected to the ends of the wire, the voltmeter would indicate a small voltage when the wire is moved across the magnetic field. This induced voltage will be dependent on three factors. These factors can be listed as follows:

1. The strength of the magnetic field.

2. The speed at which the lines of force are cutting across the conductors.

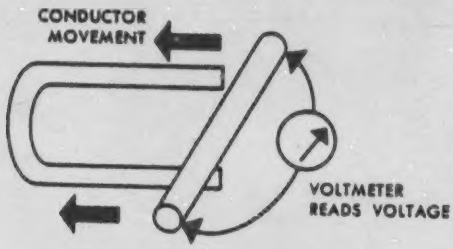

Figure 25. Electromagnetic Induction.

3. The number of conductors that are cutting across the lines of force.

Remember that magnetism is a connecting link between mechanical energy and electricity. Without the effects of magnetism there could be no generators, alternators or motors for charging batteries, cranking engines, etc. The principle of electromagnetic induction must be thoroughly understood.

ELECTRICAL MALFUNCTIONS AND TEST EQUIPMENT

Electrical systems on vehicles are well constructed. However, there are times when troubles will develop in electrical circuits. When this occurs, the mechanic must be able to trace any circuit by the use of schematics and test equipment.

Electrical Malfunctions

When something goes wrong in an automotive electrical circuit, it will usually fall into one of four types of malfunctions. These types of electrical malfunctions can be calssified as open circuits, short circuits, unwanted grounds, and excessive resistance.

OPEN CIRCUIT. An open circuit consists of a break in the circuit. An example of an open circuit is a wire that has come loose or a slip connection that is not making contact. If a circuit is open, no current will flow through the circuit and an ammeter would show 0 amps.

SHORT CIRCUIT. A short circuit occurs when copper touches copper, such as when two bare wires touch each other. Current is given a shorter path to travel through and some of the resistance in the circuit is by-passed. A short circuit always results in a higher than normal current flow through all or part of the circuit that is shorted.

UNWANTED GROUND. An unwanted ground occurs whenever any part of the wiring touches the vehicle frame before it is supposed to. An unwanted ground involves accidental or unintentional contact between copper and the iron frame of the vehicle.

EXCESSIVE RESISTANCE, THE TROUBLEMAKER. Excessive resistance can be caused by many different things. Excessive resistance is generally the most difficult malfunction for the mechanic to find.

It can be caused by dirty or loose connections, frayed wiring, corrosion, a wire too long, and many other things. A good voltmeter is a must to allow the mechanic to measure the voltage drop along a circuit to locate the points of excessive resistance.

DC Meters

Diagnosing troubles in the electrical system is one of the more important duties of the automotive electrician. To do this correctly it is important that the proper instruments are connected in the circuit in the right manner. Many of the meters you will use in the field may have more than one scale on them. You MUST know how to correctly read your test meters. If the instruments are cared for and used properly, the automotive electrician can decide whether changes or adjustments are needed. He can decide whether a unit or part needs replacement or repair. He can decide whether the system is performing satisfactorily. Each unit of an electrical system is built to a specification. To find whether it is operating to its efficiency, periodic tests are necessary. In making tests, use the equipment technical order to find the specifications.

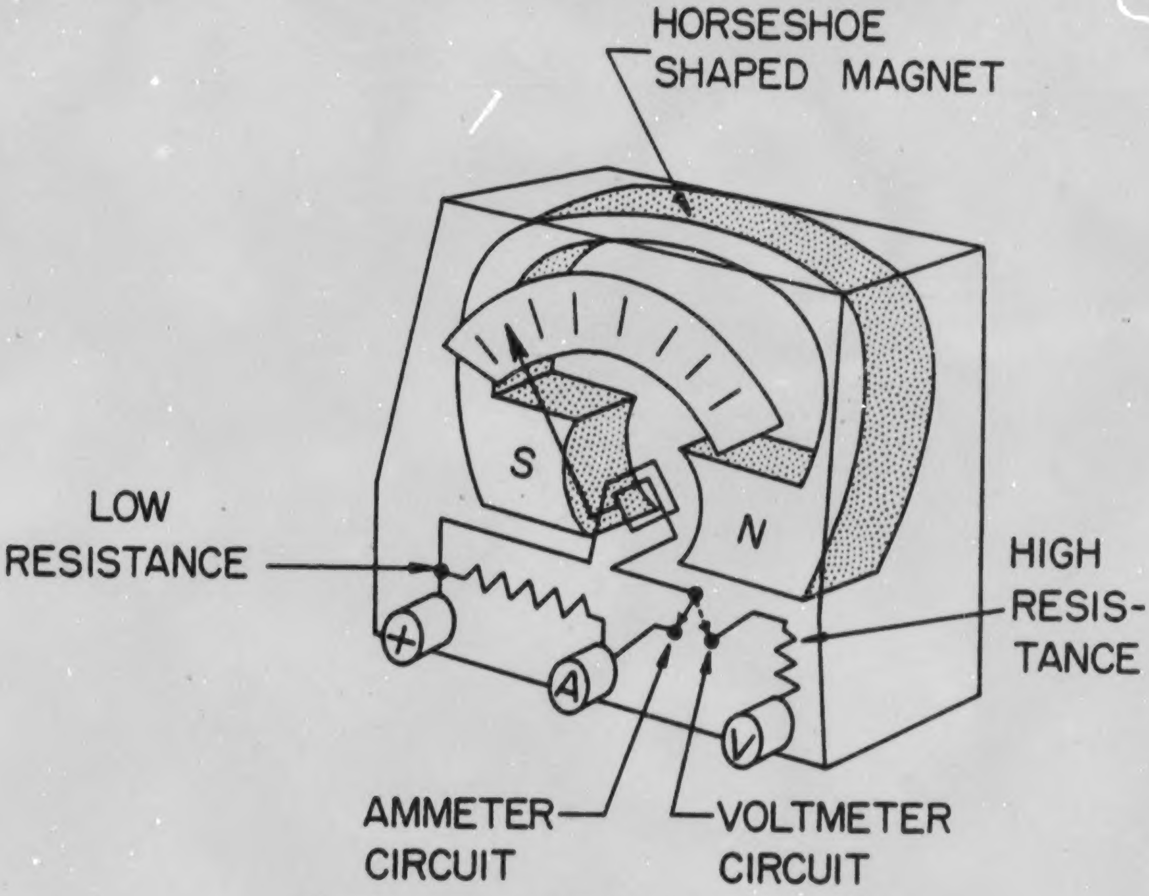

Figure 26. Moving-Coil Type Meter.

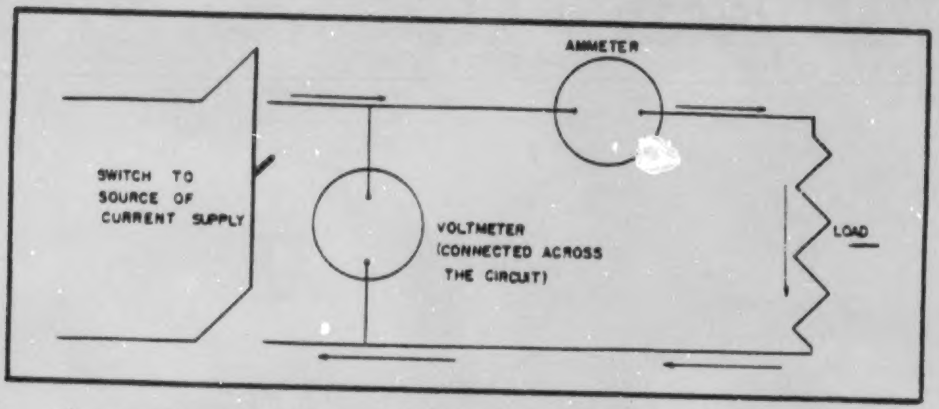
AMMETER
SWITCH TO SOURCE OF CURRENT SUPPLY
VOLTMETER (CONNECTED ACROSS THE CIRCUIT)
LOAD

Figure 27. Connecting Voltmeter and Ammeter in a Circuit.

THE VOLTMETER. Most voltmeters are of the moving-coil type. They consist of a permanent horseshoe magnet and a movable coil, figure 26. Current flowing through this movable coil reacts with the magnetic field of the horseshoe magnet (like poles repel), causing the coil to turn against a slight spring tension. A pointer is attached to the coil and moves across a scale to show the correct voltage of the circuit being tested. A voltmeter is always hooked across a circuit or parallel with the circuit, figure 27. This is a very important point to remember. The voltmeter uses very little current from the circuit and will not disturb the circuit. Therefore, the voltage of a circuit should be much the same after the voltemter is hooked up as it was before.

THE AMMETER. The ammeter is used to measure the flow of current through a circuit. The ammeter, like the voltmeter, is usually of the moving coil type, figure 26. The ammeter has very low resistance between the two terminals of the meter. This lets the meter show very accurately the amount of current flowing in the circuit. Unlike the voltmeter, the ammeter must be connected in series with the circuit being tested. Figure 27 shows the correct way to connect an ammeter into a circuit.

> Caution: Since the ammeter has a very low resistance, it must NEVER be connected across the voltage source. If connected across a voltage source, such as the battery, the meter may be instantly damaged beyond repair.

THE OHMMETER. You will probably not use an ohmmeter too often, but you should know how to use them just in case. The ohmmeter is much like the voltmeter and ammeter. However, the ohmmeter contains its own dry cell (flashlight) battery for a source of power. Ohmmeters should never be connected to an external source of power (voltage) or to a circuit that has current flowing through it, as the meter may become damaged.

CARE OF THE DC METERS. It is very important that the meters be properly cared for. The accuracy of the readings will depend upon how the meter is taken care of. If they are not cared for properly, they cannot possibly give the user an accurate reading. For the care of the meters, always refer to the correct technical order for the type meter being used. The different meters will be explained to you as you go through the course.

Electrical Symbols

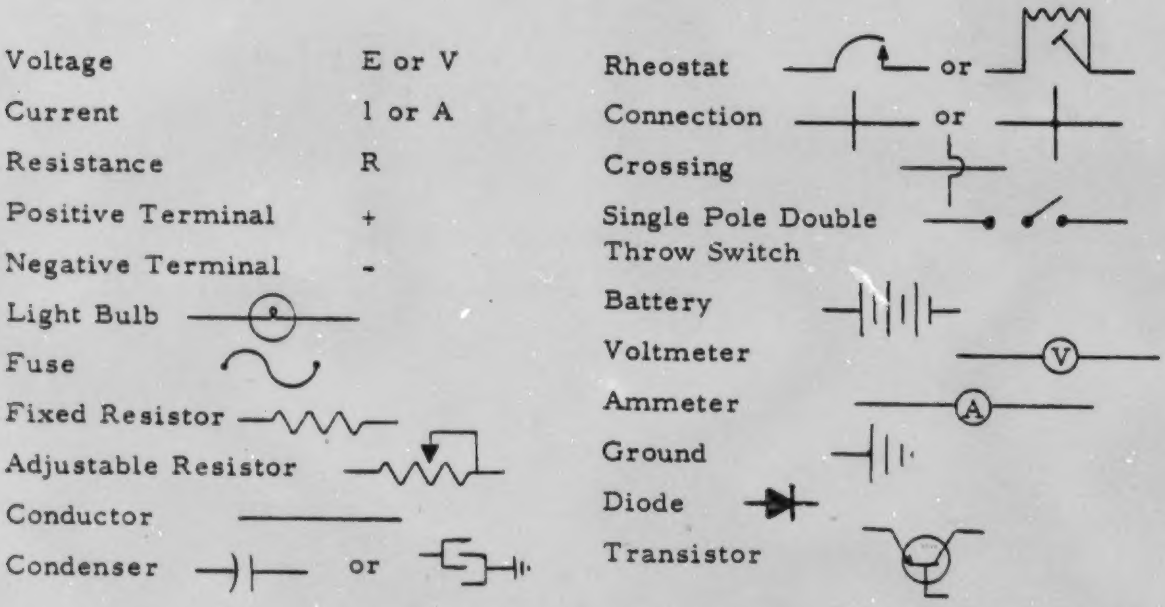
Voltage
E or V
Current
1 or A
Resistance
R
Positive Terminal
+
Negative Terminal
-
Light Bulb
Fuse
Fixed Resistor
Adjustable Resistor
Conductor
Condenser
or
Rheostat
or
Connection
or
Crossing
Single Pole Double Throw Switch
Battery
Voltmeter
V
Ammeter
A
Ground
Diode
Transistor

Figure 28. Electrical Symbols.

We have stated that automotive circuits may be classified as series, parallel, or series-parallel. In any circuit there will be electrical devices installed, such as a battery, light bulbs, resistors and switches. Many symbols are used in electrical diagrams. In electrical work, symbols are used in diagrams to represent equipment, devices and conductors. Some of the symbols are shown in figure 28. A diagram showing the connections using symbols is called a wiring diagram. A typical wiring diagram that will be found in automotive maintenance manuals or technical orders is shown in figure 29. The symbols used throughout this course are common symbols. They should be well studied. Many other symbols will be found in wiring diagrams. They will be explained whenever they appear in the course. Wiring harness cable circuit identification has been established by number coding and/or color coding. The prime purpose of wire identification is to make it easier to install a wiring harness since only the very ends of the many different wires can be seen. If number coding is used the code numbers and the circuit will be listed in the vehicle's technical order. Color coding the insulation is widely used. The color code is usually given on the wiring diagram applying to the circuit. Remember, when in doubt, consult the proper technical order for the correct information.

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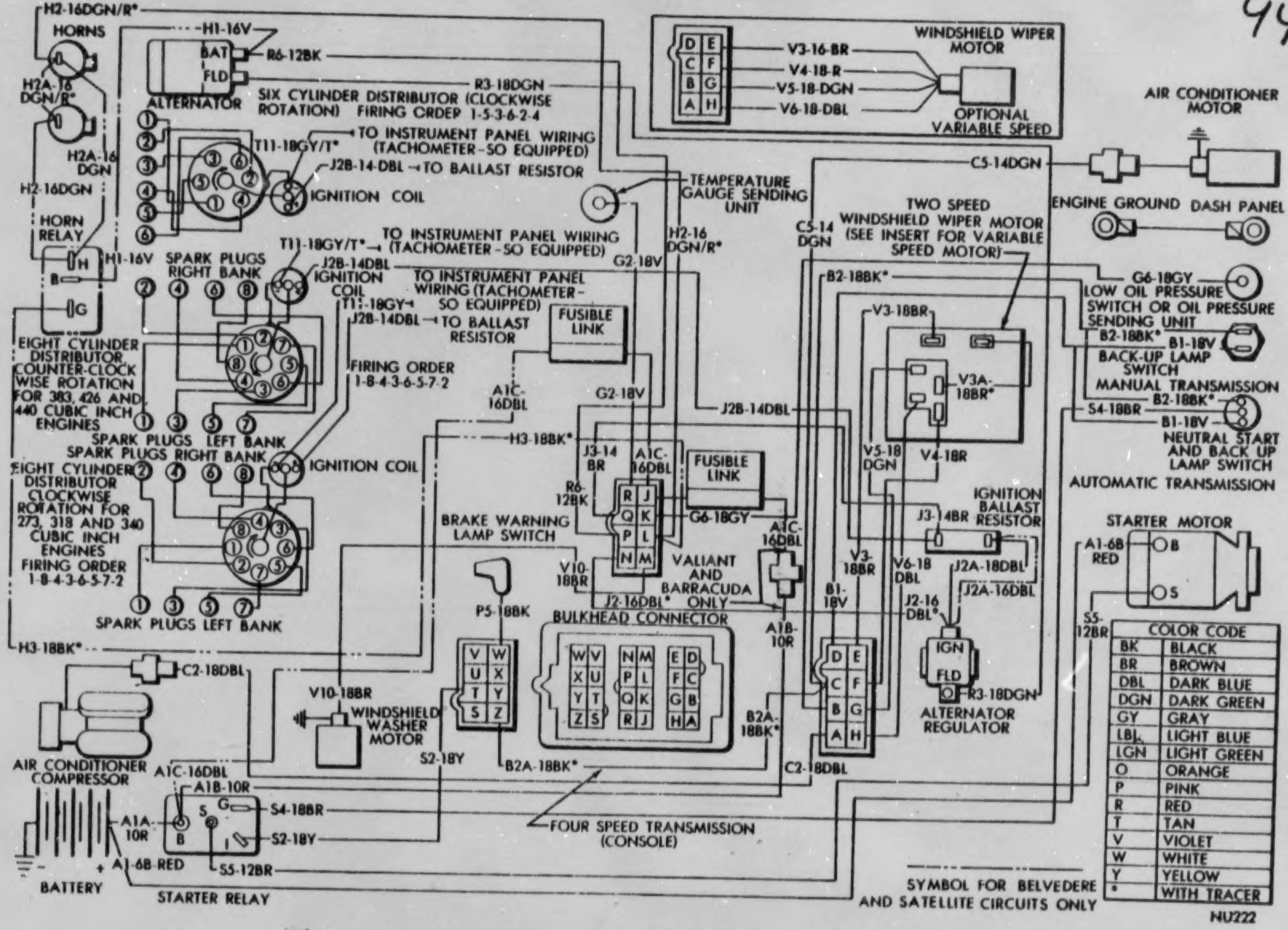

H2-16DGN/R*
HORNS
H1-16V
R6-12BK
BAT
FLD
ALTERNATOR
H2A-16 DGN/R*
H2A-16 DGN
H2-16DGN
HORN RELAY
H
B
G
H1-16V
R3-18DGN
SIX CYLINDER DISTRIBUTOR (CLOCKWISE ROTATION) FIRING ORDER 1-5-3-6-2-4
T11-18GY/T*
TO INSTRUMENT PANEL WIRING (TACHOMETER-SO EQUIPPED)
J2B-14-DBL → TO BALLAST RESISTOR
IGNITION COIL
TEMPERATURE GAUGE SENDING UNIT
T11-18GY/T* → TO INSTRUMENT PANEL WIRING (TACHOMETER-SO EQUIPPED)
J2B-14DBL
SPARK PLUGS RIGHT BANK
IGNITION COIL
TO INSTRUMENT PANEL WIRING (TACHOMETER-SO EQUIPPED)
T11-18GY
J2B-14DBL → TO BALLAST RESISTOR
H2-16 DGN/R*
G2-18V
FUSIBLE LINK
EIGHT CYLINDER DISTRIBUTOR COUNTER-CLOCK WISE ROTATION FOR 383, 426 AND 440 CUBIC INCH ENGINES
FIRING ORDER 1-8-4-3-6-5-7-2
A1C-16DBL
SPARK PLUGS LEFT BANK
SPARK PLUGS RIGHT BANK
IGNITION COIL
H3-18BK*
G2-18V
J3-14 BR
A1C-16DBL
R6-12BK
FUSIBLE LINK
EIGHT CYLINDER DISTRIBUTOR CLOCKWISE ROTATION FOR 273, 318 AND 340 CUBIC INCH ENGINES FIRING ORDER 1-8-4-3-6-5-7-2
BRAKE WARNING LAMP SWITCH
G6-18GY
A1C-16DBL
V10-18BR
VALIANT AND BARRACUDA ONLY
J2-16DBL*
SPARK PLUGS LEFT BANK
P5-18BK
BULKHEAD CONNECTOR
A1B-10R
H3-18BK*
C2-18DBL
V10-18BR
WINDSHIELD WASHER MOTOR
AIR CONDITIONER COMPRESSOR
S2-18Y
B2A-18BK*
B2A-18BK*
C2-18DBL
A1C-16DBL
A1B-10R
A1A-10R
S4-18BR
S2-18Y
S5-12BR
A1-6B-RED
BATTERY
STARTER RELAY
FOUR SPEED TRANSMISSION (CONSOLE)
WINDSHIELD WIPER MOTOR
V3-16-BR
V4-18-R
V5-18-DGN
V6-18-DBL
OPTIONAL VARIABLE SPEED
AIR CONDITIONER MOTOR
C5-14DGN
ENGINE GROUND
DASH PANEL
C5-14 DGN
TWO SPEED WINDSHIELD WIPER MOTOR (SEE INSERT FOR VARIABLE SPEED MOTOR)
B2-18BK*
G6-18GY
LOW OIL PRESSURE SWITCH OR OIL PRESSURE SENDING UNIT
V3-18BR
B2-18BK*
B1-18V
BACK-UP LAMP SWITCH
MANUAL TRANSMISSION
V3A-18BR*
J2B-14DBL
B2-18BK*
S4-18BR
B1-18V
NEUTRAL START AND BACK UP LAMP SWITCH
AUTOMATIC TRANSMISSION
V5-18 DGN
V4-18R
IGNITION BALLAST RESISTOR
J3-14BR
STARTER MOTOR
A1-6B RED
V3-18BR
V6-18 DBL
J2A-18DBL
J2A-16DBL
B1-18V
J2-16 DBL*
IGN
FLD
R3-18DGN
ALTERNATOR REGULATOR
S5-12BR
SYMBOL FOR BELVEDERE AND SATELLITE CIRCUITS ONLY
NU222

COLOR CODE	
BK	BLACK
BR	BROWN
DBL	DARK BLUE
DGN	DARK GREEN
GY	GRAY
LBL	LIGHT BLUE
LGN	LIGHT GREEN
O	ORANGE
P	PINK
R	RED
T	TAN
V	VIOLET
W	WHITE
Y	YELLOW
*	WITH TRACER

Figure 29. Engine Compartment Wiring Diagram - Typical.

SUMMARY

Due to the length of this part of the lesson, a brief review by means of summary questions will be given at this time. But remember, the service technician who has a good knowledge of electrical fundamentals and knows how to use his test meters will soon find that his job becomes much easier.

Questions

1. The exact nature of electricity is not known, but it can make itself evident by effects. What are four effects of electricity?

2. There are several kinds of electrical conductors. What are the three considered to be the best and in their proper order?

3. What unit of measurement is used to measure a flow of current?

4. What unit of measurement is used to measure the force of movement behind current?

5. What is voltage drop and how is it useful?

6. What is the difference between a series circuit and a parallel circuit?

7. How can the magnetic lines of force in an electromagnet be increased?

8. Magnets have north and south poles. Which poles attract and which poles repel each other?

9. In measuring the flow of current in a circuit, would you connect the instrument in series or parallel?

10. What materials are usually used in permanent magnets?

11. Ohm's Law can be summed up as the relationship between resistance, current and voltage. State Ohm's Law.

12. What determines the strength of an electromagnet and what term is used to express this?

13. What are three rules of Ohm's Law?

14. What is a circuit?

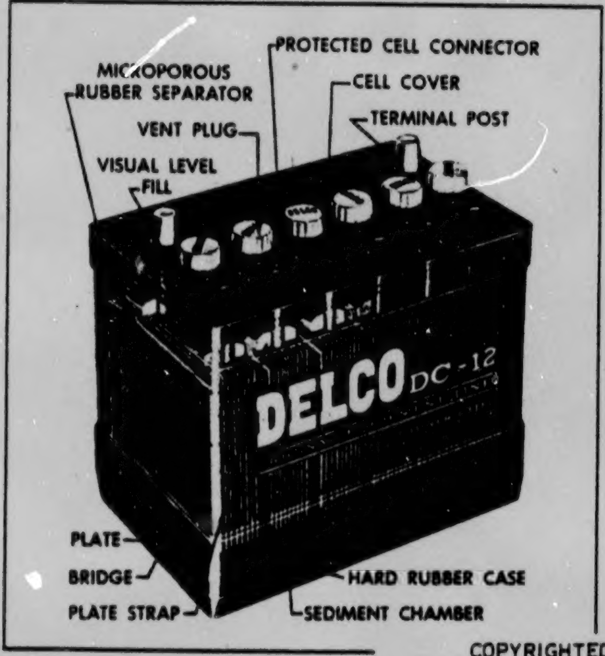
15. How is wiring harness circuit identification established?

SECTION II
PRINCIPLES OF BATTERIES

The previous section of this lesson covers the principles of electricity and magnetism. We said that electricity is not visible but that it does make itself evident by one of four effects. One of these effects is chemical electricity. Chemical electricity is produced through a combination of chemicals and various kinds of metals. The reaction that takes place produces electricity, such as in a storage battery. The following information concerns the construction and operation of the type of storage battery used in the automobile.

The lead-acid storage battery is an electrochemical device for converting chemical action into electrical energy. It is not a storage tank for electricity, as is often thought, but instead, stores electrical energy in chemical form. The battery performs three functions in the automobile. First, it supplies current to the cranking motor and the ignition system as the engine is started. Second, it supplies current for the lights, radio, heater and other accessories when the electrical demand of these devices exceeds the output of the generator or alternator. Third, the battery acts as a voltage stabilizer in the electrical system. Satisfactory operation of the vehicle is impossible unless the battery performs each of these important functions.

Construction


PROTECTED CELL CONNECTOR
MICROPOROUS RUBBER SEPARATOR
CELL COVER
TERMINAL POST
VENT PLUG
VISUAL LEVEL FILL
DELCO DC-12
PLATE
BRIDGE
PLATE STRAP
HARD RUBBER CASE
SEDIMENT CHAMBER

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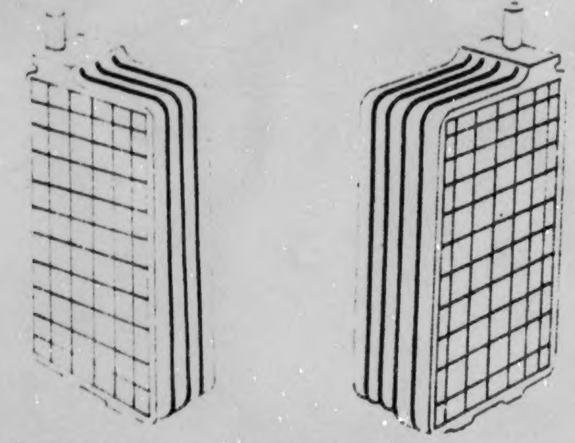
PONTIAC MOTOR DIVISION

Figure 30. Battery.

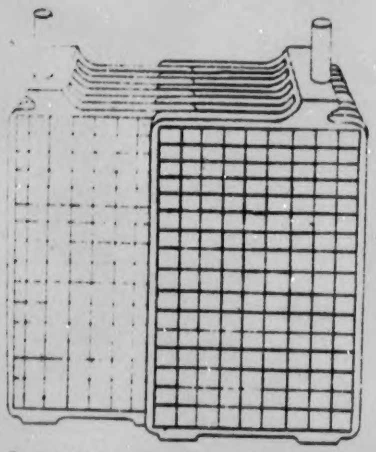
The construction of an automotive lead-acid storage battery, figure 30, is such that a highly reliable source of power is provided. Storage batteries have three or more cells depending on the voltage required. A battery of three cells connected is series is called a 6-volt battery. A battery of six cells connected in series is called a 12-volt battery.



Positive Plate Group.

Negative Plate Group.

Figure 31. Plate Groups.



Positive Plates Between Negative Plates

Figure 32. Assembly of Plate Groups.

THE BATTERY CELL. A battery cell is made up of two types of plates, one called a positive plate and the other called a negative plate. Actually, there are many such plates in a battery cell. The negative plates contain sponge lead (Pb). The positive plates contain lead peroxide (PbO_2). The cell plates are a grid-like structure, figure 31. This makes the plate more rigid and provides more area to be exposed to the acid in the cell. Several plates are joined together by a plate strap casting to form what is called a positive group and a negative group, figure 32. The plates, which are immersed in a sulphuric acid solution (H_2SO_4) (called electrolyte), are separated by thin sheets of porous insulating material called separators.

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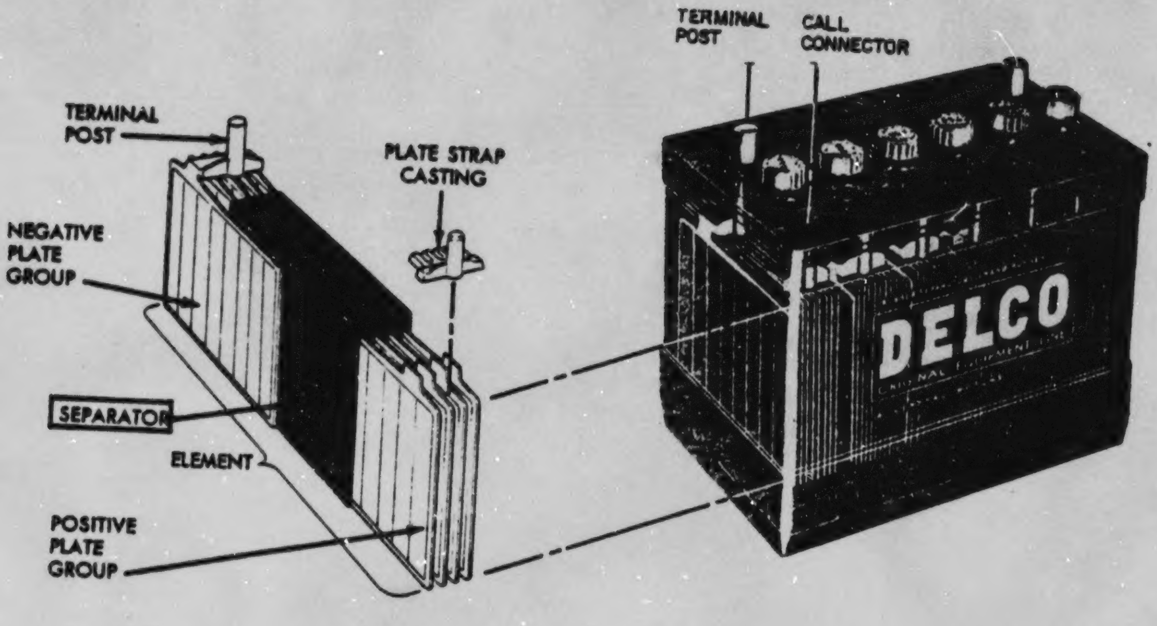
TERMINAL POST
CALL CONNECTOR
TERMINAL POST
PLATE STRAP CASTING
NEGATIVE PLATE GROUP
SEPARATOR
ELEMENT
POSITIVE PLATE GROUP
DELCO

Figure 33. Cell Construction.

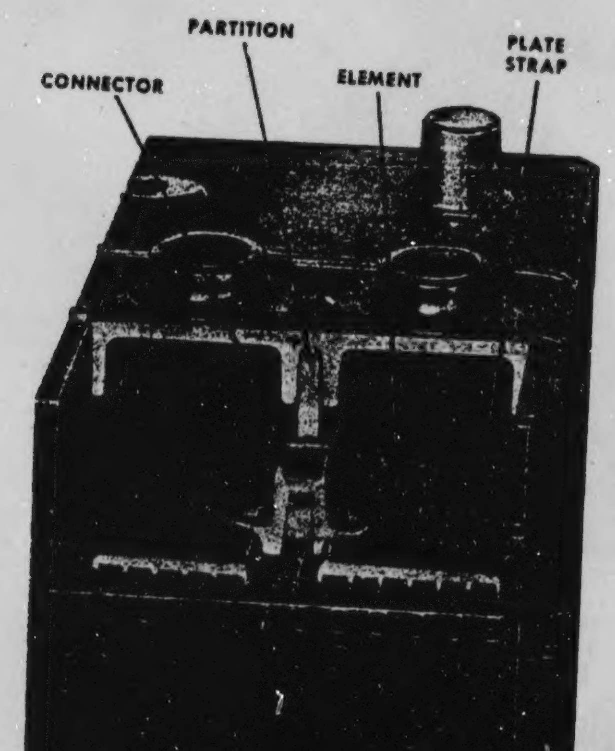
PARTITION
PLATE STRAP
CONNECTOR
ELEMENT

Figure 34. Internal View of Energizer.

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Separators are between the plates to prevent them from touching and causing a short circuit. Each cell of a lead-acid battery will produce approximately two volts. The cells of a battery are then connected in series to obtain the required voltage of the battery. The construction of a typical cell is shown in figure 33. A new type of battery called an "Energizer" is now being used in many new automobiles as standard equipment. The construction of the "Energizer" cell is basically as described above although each part is called by a different name, see figure 34.

THE CASE CONTAINS THE CELLS. After the cell components are assembled, they are placed in a battery case. The case is made of molded plastic or hard rubber. This makes the case very strong and, in the case of plastic, lighter in weight In the bottom of the case are sediment chambers. Particles of lead which fall off of the plates are kept safely out of the way in the sediment chamber where they will cause no harm to the battery.

VENT CAPS ARE THERE FOR MORE THAN ONE REASON. A vent cap is located in each cell cover and serves two purposes. First, it closes the opening in the cell cover through which electrolyte can be checked and water added. Secondly, it provides a means for the escape of gases formed during charging of the battery. This prevents the battery from possibly exploding!

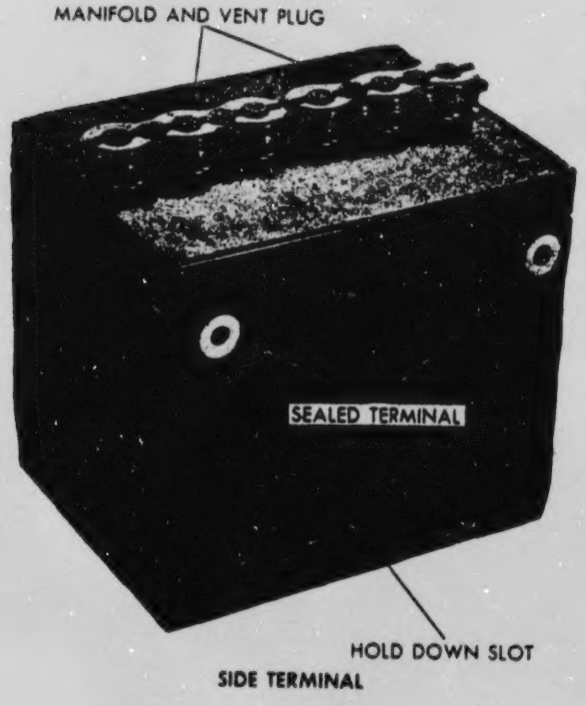

Figure 35. Energizer With Side Terminals.

POSTS PROVIDE THE CONNECTIONS. Electrical connection to the battery is made through the battery posts. One post is marked positive and the other negative. If the posts are not marked, the positive post is the larger of the two. Most battery posts are mounted on the top of the battery. However, some new "Energizers" now have the posts side-mounted, see figure 35. These batteries require a special connecting adapter when recharging the battery or attempting to "jump start" the vehicle.

Operation of the Lead-Acid Battery

When a battery cell is fully charged, the negative plate is spongy lead (Pb), the positive plate is lead peroxide (PbO_2), and the electrolyte contains a maximum of sulphuric acid (H_2SO_4). Both plates are porous. They are readily acted upon by the acid. A cell in this condition can produce electrical energy through the reaction of the chemicals.

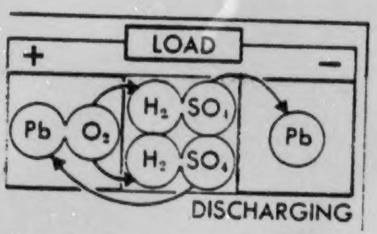

Figure 36. Chemical Action of Discharging Battery.

DISCHARGING THE BATTERY. If the terminals of the battery are connected to a closed circuit, the cell discharges to supply electric current. The chemical process that occurs during discharge changes both the sponge lead of the negative plate and the lead peroxide of the positive plate to lead sulphate ($PbSO_4$) and the sulphuric acid to water (H_2O), refer to figure 36. Thus the electrolyte becomes weaker during discharge, since the water increases and the sulphuric acid decreases. As the discharge progresses, the negative and positive plates finally contain considerable lead sulphate. The discharge should always be stopped before the plates have entirely changed to lead sulphate. Sulphated plates may result in permanent damage to the battery. To better understand this chemical reaction, the action that takes place can be summed up as follows. The sulphuric acid is absorbed by the plates to produce current. So when the electrolyte has been reduced to water, the battery is in a discharged condition.

RECHARGING THE BATTERY IS NEXT. To charge the cells, an external source of direct current must be connected to the battery terminals. The chemical action is then reversed and returns the positive and negative plates to their original condition. When all the sulphate on the plates has been returned to the electrolyte to form sulphuric acid, the cell has been fully recharged. It is ready to be used for the next discharge. Chemical action for charging the battery cell is shown in figure 37.

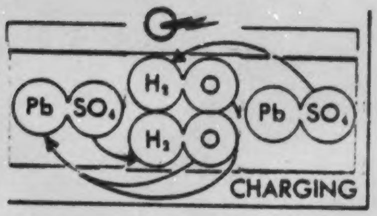

Figure 37. Battery Charging.

Battery Capacity

The two most common battery ratings are the 20-Hour Rate at 80°F and the Cold Rating at 0°F. The 20-Hour Rating indicates the lighting and accessory load capacity of the battery and the Cold Rating indicates the cranking load capacity.

THE 20-HOUR RATING. The 20-Hour Rating in ampere-hours is determined by laboratory testing. The battery is fully charged. With the battery temperature maintained at 80°, the battery is discharged at a constant rate for twenty hours. At the end of this time the cell voltage must remain above 1.75 volts. A battery that can supply 5 amps under these conditions would be given a rating of 100 ampere-hours. (5 amps X 20 hours = 100 ampere-hours).

THE COLD RATING. The Cold Rating is obtained by discharging a fully charged battery at 0°F at a constant rate of 150 or 300 amps, depending on the voltage and ampere-hour rating of the battery. Two ratings are given. One is the voltage obtained after 10 seconds of discharge, the other is the time in minutes for a battery to reach its end voltage. A battery having a 10-second rating of 7.6 volts at 300 amps will maintain a voltage of 7.6 volts or higher for 10 seconds. A battery having a time rating of 2 minutes will operate under the above conditions for 2 minutes before the end voltage is reached. The higher the 10 second voltage rating and the higher the time rating, the greater will be the cranking capacity of the battery.

"ENERGIZERS" ARE RATED IN WATTS. "Energizers" are rated in watts, which is a measure of the cranking ability of the "Energizer" at cold temperatures. The wattage rating is determined by laboratory testing and is obtained by multiplying the voltage by the current. The peak wattage is used in rating "Energizers" at the temperature involved. Thus, by comparing wattage ratings, an immediate comparison between "Energizers" of cranking abilities is obtained.

Factors Affecting Battery Life

There are various factors which affect the life of a battery. Of these, the more important include overdischarging, rapid charging and rapid discharging. Overdischarging or allowing a battery to remain in a discharged condition for a long period of time causes excess sulphation of the plates. When this condition is reached, it is almost impossible to charge the battery. Too rapid charging or discharging causes overheating and warping of the plates. Excess shedding of active plate material results, reducing battery capacity.

BATTERY SERVICING AND TESTING

When trouble is experienced in any electrical circuit, the battery cannot be overlooked as a possible source of trouble. Since a visual inspection and a few electrical checks will readily reveal the condition of the battery, it is always advisable to start all circuit checks by checking the battery first. Otherwise, a component part of some circuit, failing to function properly, may be unjustly condemned. If the battery is proven defective, it should be replaced. If it is found to be merely overcharged or undercharged, further checks may be necessary.

Battery Servicing

Most electrical troubles caused by battery failures can be prevented by systematic battery service. A large number of premature battery failures can be eliminated if four important points are considered.

CORRECT APPLICATION IS A MUST. Long and trouble-free service can be expected only when the amper-hour capacity is balanced with the electrical load. The use of an undersized battery will result in poor performance or early failure. When a new battery is installed in the vehicle, the replacement battery should be at least of equal ampere-hour rating to the original battery.

PROPER ACTIVATION IS NECESSARY. Proper activation of dry charged batteries is extremely important because improper activation always results in poor performance or early failure. The hydrometer test, which will be discussed in the battery testing section later, will determine if the battery has been properly activated.

CORRECT INSTALLATION IS IMPORTANT. Correct installation of a battery is also important since case or cover breakage may result from improper handling and installation. The hold-down bolts should be kept tight enough to prevent the battery from shaking in its holder, which could damage the case. However, they should not be tightened to the point where the battery case will be placed under a severe strain. The battery carrier should be clean and free from corrosion before installing a battery. Corrosion on the carrier will increase the rate of corrosion on the carrier and keep it level. The battery should be installed in its carrier with the positive and negative posts in the proper position. Reversing the battery polarity can lead to generator regulator or ignition problems.

> Caution: When installing batteries, the ground cable at the battery terminal should be disconnected first and reconnected last to avoid damage to the battery and wiring by accidental grounds with tools.

PERIODIC SERVICE IS AN ABSOLUTE NECESSITY! A battery is a perishable item which requires periodic servicing. Therefore a good maintenance program for the battery will insure the longest possible battery life.

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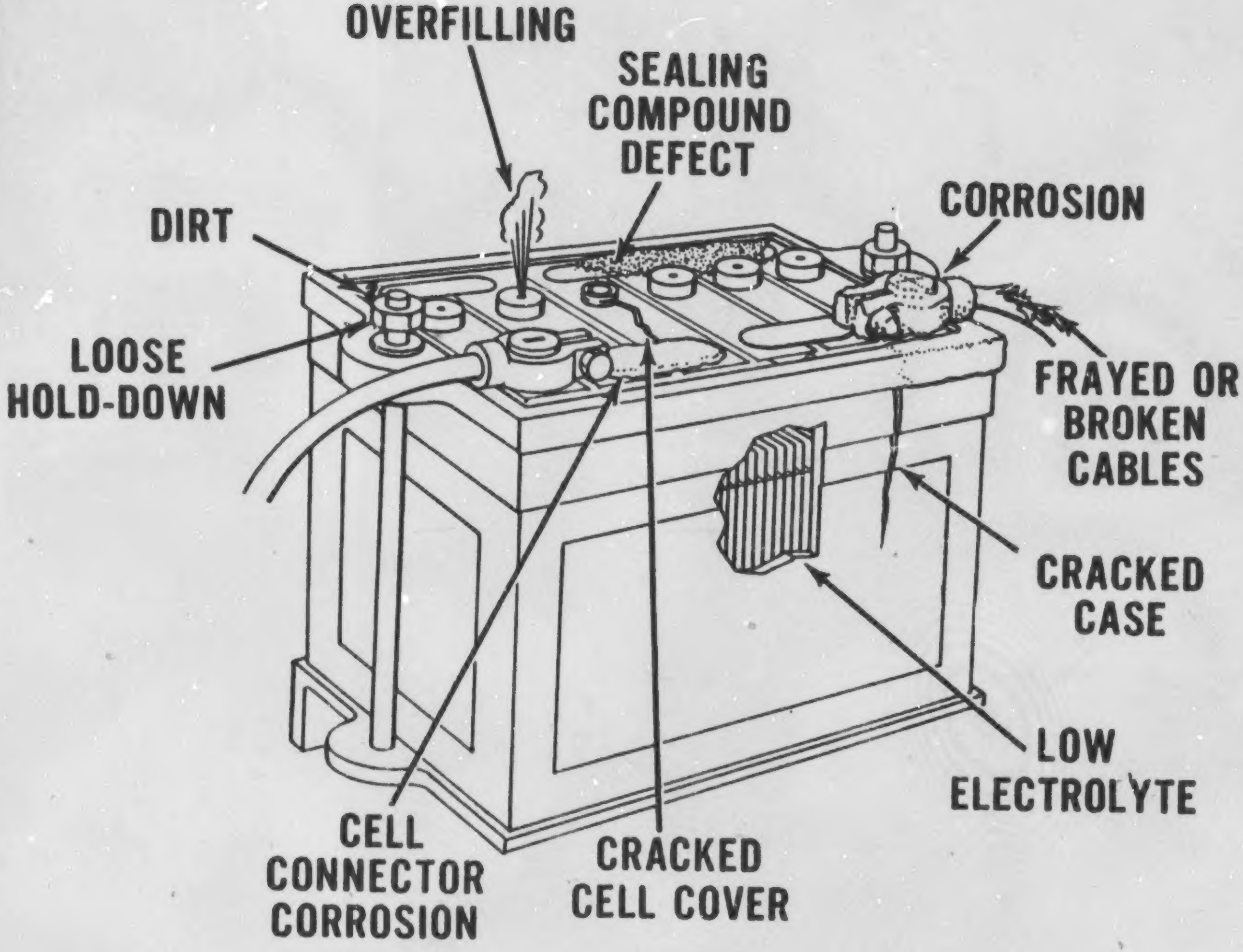

OVERFILLING
SEALING COMPOUND DEFECT
CORROSION
DIRT
LOOSE HOLD-DOWN
FRAYED OR BROKEN CABLES
CRACKED CASE
LOW ELECTROLYTE
CELL CONNECTOR CORROSION
CRACKED CELL COVER

Figure 38. Battery Visual Inspection.

104

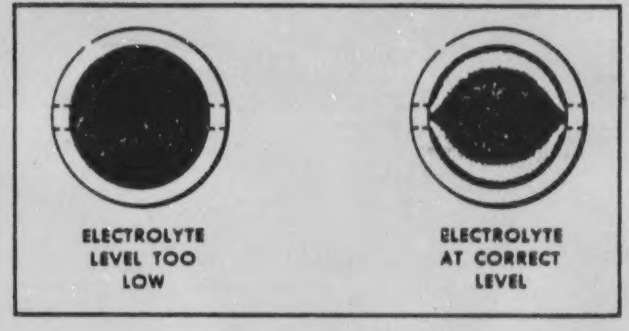
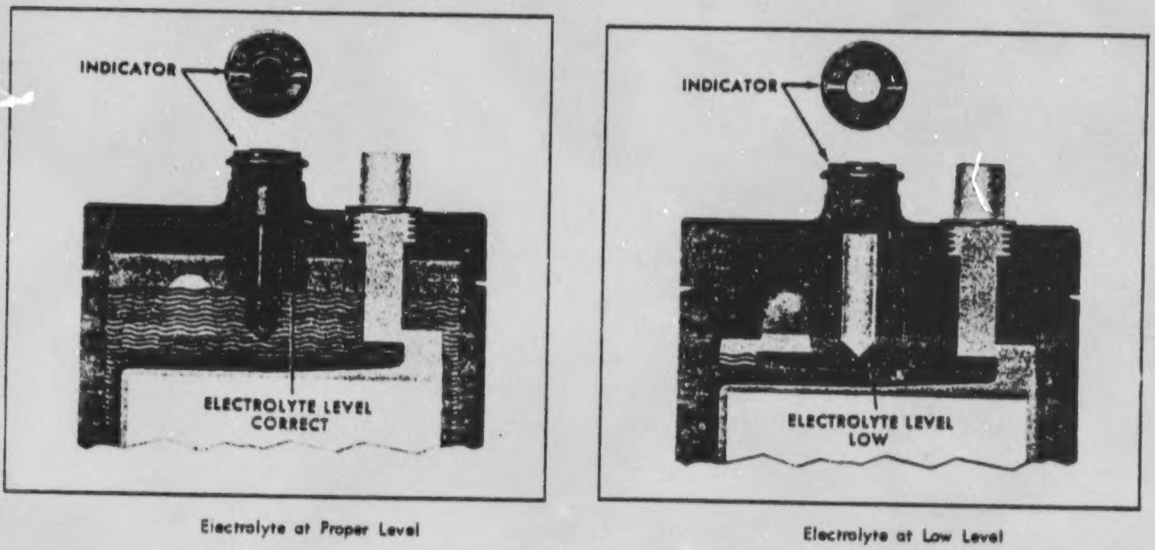

ELECTROLYTE LEVEL TOO LOW
ELECTROLYTE AT CORRECT LEVEL

Figure 39. View Inside Vent Well.


INDICATOR
ELECTROLYTE LEVEL CORRECT
INDICATOR
ELECTROLYTE LEVEL LOW

Electrolyte at Proper Level

Electrolyte at Low Level

Figure 40. Checking Electrolyte Level Using Eye.

Check Electrolyte Level Frequently. The electrolyte level, figure 38, should be checked every 2,000 miles or once a month. In hot weather, particularly during trip driving, checking should be more frequent because of more rapid loss of water. If the electrolyte level is found to be low, distilled water or tap water should be added to each cell. Add water to the split ring in the bottom of the vent well, figure 39, or until the "eye" is dark, figure 40. Do not overfill the battery as this will cause loss of electrolyte. Loss of electrolyte will result in poor battery performance and also will cause corrosion. Only water should be added to the battery, never acid.

> Note: The water level in the cells should never be allowed to go below the top of the plates as permanent sulphation will result.

External Condition Must Be Kept Clean. The external condition of the battery should be checked periodically for damage such as a

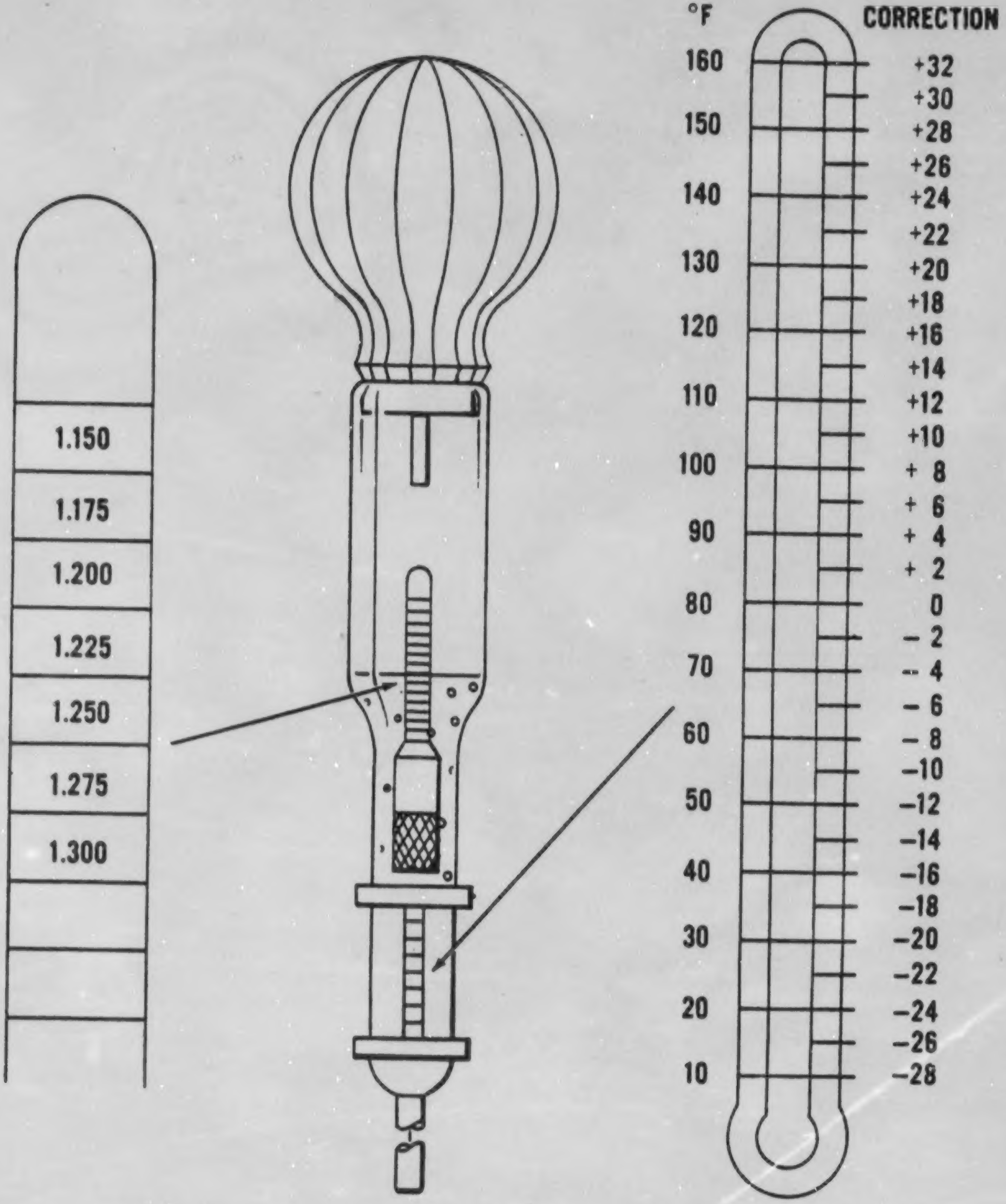

1.150
1.175
1.200
1.225
1.250
1.275
1.300
°F
CORRECTION
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
+32
+30
+28
+26
+24
+22
+20
+18
+16
+14
+12
+10
+ 8
+ 6
+ 4
+ 2
0
– 2
– 4
– 6
– 8
–10
–12
–14
–16
–18
–20
–22
–24
–26
–28

Figure 41. A Batter Hydrometer.

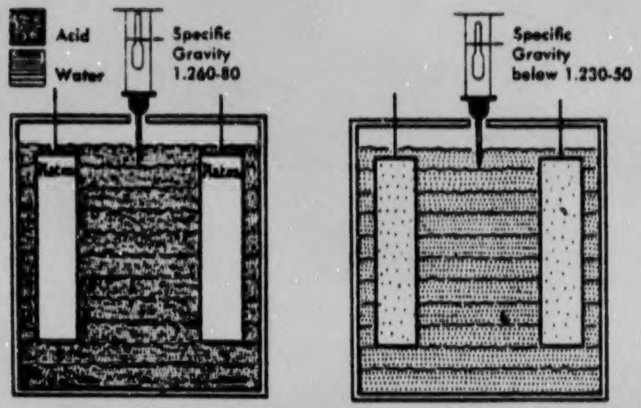
broken case or broken cell covers, figure 38. The top of the battery should be kept clean. This is particularly important for 12-volt batteries where acid and dirt may permit current to flow between the battery terminals. This will result in slow battery self-discharge. For best results when cleaning the top of batteries, wash first with a solution of baking soda and water to neutralize any acid present. The battery top should then be flushed off with clean water. Care must be taken to keep vent plugs tight, so that the neutralizing solution does not enter the cells.

Electrical Contact Should be Clean and Tight. To insure good electrical connections, the battery cables should be clean and tight on the battery posts, figure 38. If the battery posts and cable terminals are corroded, the cables should be disconnected. The terminals and clamps are then cleaned separately using a battery cleaning tool or a solution of baking soda and water and a wire brush. After cleaning and reconnecting the cables, apply a thin coating of vasoline on the posts and cable clamps to help reduce corrosion. Some manufacturers also recommend that a felt washer be placed on the battery post underneath the cable clamp to help reduce the corrosion of the terminals.

Battery Testing

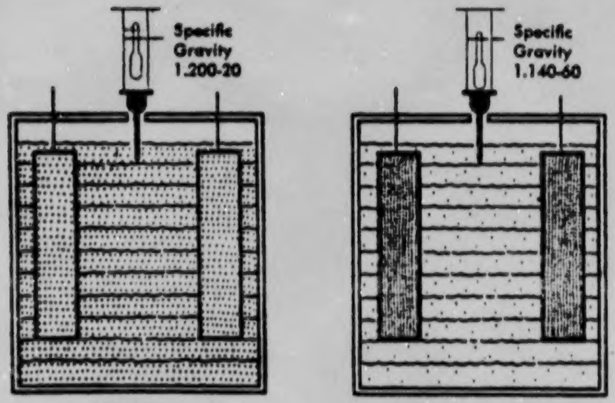
While taking proper care of the battery will insure a long and useful life under most conditions, the battery must be tested occasionally to check its state of charge and internal condition.

THE BATTERY HYDROMETER TEST CHECKS THE STATE OF CHARGE. The state of charge of a storage battery depends upon the active material on the plates and the strength of the electrolyte. Other than charge the battery, you can do nothing to increase the active plate material. However, you can check the electrolyte of the battery to find the state of charge. Use an instrument called a battery hydrometer. You are checking the specific gravity (weight of sulphuric acid compared to water) of the electrolyte. The hydrometer is a small glass tube, weighted in its lower end so it will float upright when the electrolyte is drawn into the tube. Part of the hydrometer is shown in figure 41. The hydrometer is calibrated from 1.150 to 1.300. The number 1.300 is on the lower end of the float, figure 41. The depth which the weighted glass tube sinks into the electrolyte is determined by the density of the electrolyte. The more dense the electrolyte, the higher the hydrometer will float. A fully charged battery has a specific gravity reading of, or about 1.280 on the hydrometer (80° temperature), figure 42. An undercharged battery would show as a specific gravity reading of 1.225 or below, figure 42.



FULLY CHARGED
Acid in water gives electrolyte specific gravity of 1.270.

GOING DOWN
As battery discharges, acid begins to lodge in plates. Specific gravity drops.



UNSAFE!
Battery half discharged. More acid in plates, less in electrolyte. Starting failure in sight if battery is allowed to remain in car.

DISCHARGED
Acid almost entirely in plates, leaving weak electrolyte behind. Specific gravity lower, almost that of water.

During discharge, as acid combines with both Plate Materials, Hydrometer sinks lower. Note changing position of black dots in illustrations.

Figure 42.

Note: Correct the specific gravity readings for electrolyte temperature. When the electrolyte temperature is above 80 degrees F., add 4 points (.004) to the hydrometer reading for every 10 degrees above 80 degrees. When the electrolyte temperature is below 80 degrees, subtract 4 points for each 10 degrees below 80 degrees.

Caution: Make sure the battery is fully charged because hydrometer readings taken on partially charged batteries are unreliable. Never make a hydrometer test immediately after water has been added to a battery. It is important that the eye be approximately at the liquid level when the reading is taken. Readings taken at a sharp angle usually are very inaccurate.

THE BATTERY CAPACITY TEST CHECKS THE INTERNAL CONDITION. The hydrometer test shows only the chemical condition of the battery. It does not show the electrical condition of the battery. In other words, it does not show how much active material is still available to furnish current or if the separators are still keeping the plates from touching. To check the internal condition of the battery, a battery capacity test is made. This means that the battery must be tested by applying a specific load on it. Since test procedures will differ depending upon the type of test equipment being used, be sure to refer to the proper technical order or manual for the tester being used.

Battery Charging

There are two methods of recharging an undercharged battery. One is the slow charge method. and the other is the fast charge method. As the names imply, they differ in the length of time the battery is charged and the amount of charging current supplied.

THE SLOW CHARGE IS BEST. The slow charge method supplies the battery with a low charging rate for a long period of time. The charging rate should be about 5 amps. Charging periods of twenty-four hours and more may be needed to bring the battery to full charge. The battery is fully charged when there is no change in specific gravity readings over a three hour period.

FAST CHARGING IS QUICK. This method supplies the battery with a high charging rate for a short period of time. Charging rates of 40-70 amperes are common, with charge periods varying up to three hours maximum. A battery cannot be fully recharged by the fast charged method, although it can be "boosted." To completely recharge the battery, the fast charge method should be followed with a slow charge for a few hours.

> Caution: Never allow the electrolyte temperature to exceed 125°F when recharging a battery by either method. Permanent damage could result to the battery. Also, batteries that are recharging give off a highly explosive gas. Be sure the area is well ventilated to prevent an explosion.

Connecting Batteries Together

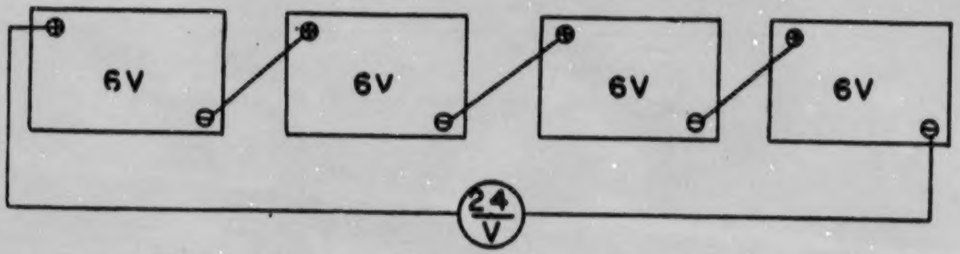


Figure 43. Connecting Batteries in Series.

Storage batteries may be connected in two different ways to obtain various voltages and amperages. The two ways of connecting batteries

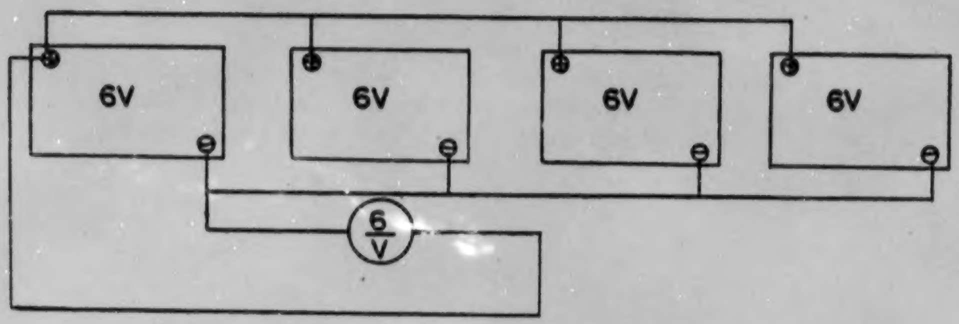


Figure 44. Connecting Batteries in Parallel.

are in series and in parallel. Connecting batteries in series will increase voltage. For example, if a voltmeter was installed in a circuit with four 6-volt batteries connected in series, figure 43, the voltmeter will show 24 volts. However, connecting the batteries in parallel, figure 44, will not increase voltage. This will increase the amperage rate. In other words, by connecting 6-volt batteries in parallel the 6 volts are maintained. The six volts will last longer under use because the ampere-hours are increased. In the series circuit the connections are from positive to negative. In the parallel circuit they are from positive to positive and negative to negative.

SUMMARY

Becoming thoroughly familiar with the contents of Sections I and II of this lesson will not necessarily make an automotive electrician. However, if the automotive electrician is throughly familiar with the principles of electricity, magnetism, circuits, and storage batteries, he should be able to do a more precise and quicker job of testing and servicing automotive electrical systems. To insure the subject is familiar, a review of the entire lesson should be made at this time by answering the summary questions which follow.

QUESTIONS

1. Resistance is opposition to current flow. What is the purpose of resistance?

2. Electrical symbols are used in place of devices in a schematic diagram. Draw eight basic symbols of a schematic diagram.

3. When connecting storage batteries together to increase voltage, how are they connected?

4. How are batteries connected together to increase amperage rates?

5. According to Ohm's Law, how many amperes will be flowing through a circuit which is connected to a 15-volt source if the circuit has a 3-ohm resistor installed in it?

6. How many volts would have to be connected to a circuit in order to produce a 4-ampere flow through a 6-ohm resistance?

7. What safety precautions would you observe while working on automotive electrical circuits?

8. What effect does temperature have on resistance of the wire in a circuit?

9. On a straight wire conductor where are the number of lines of force the greatest?

10. What are three methods of inducing current into a conductor?

11. Briefly explain how a storage battery works.

12. What separates the plates in an automotive battery?

13. What is the purpose of the specific gravity test of an automotive battery?

14. Why is the frame of a vehicle included as one of the components which make up the electrical circuit?

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-SG-302

BATTERY AND MAGNETO IGNITION SYSTEMS

OBJECTIVES

After completing this study guide and your classroom instruction, you will be able to explain the operating principles, function and construction of vehicle ignition systems. You will also be able to perform maintenance, test and adjust the ignition system components and use special test equipment.

INTRODUCTION

One of the most interesting subjects in the study of automotive electricity is the ignition system. Having the responsibility of providing a high voltage in the right order at the right time, the ignition system can supply 300 high voltage surges every second at high engine speeds. Since ignition systems cause the majority of engine troubles, you must understand the operating principles, function, and construction of the various units of these systems.

INFORMATION

Spark ignition systems may be divided into two classes. These are battery and magneto. These two systems are much the same. Both systems furnish a spark to each cylinder at a proper moment to fire compressed gasses to get the maximum energy from the power stroke of the engine.

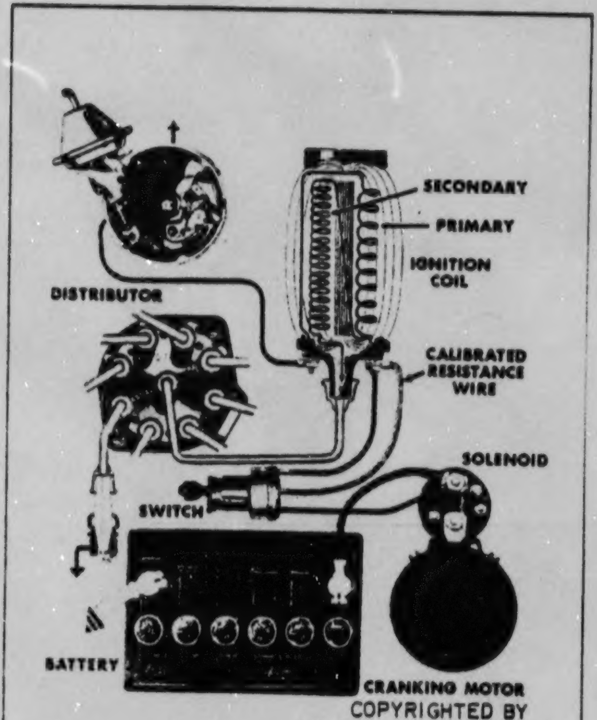


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Figure 45. Ignition Circuit.

The battery ignition system, figure 45, consists of a battery, a series of wires and cables, ignition switch, ammeter (not shown), ignition resistor, coil, distributor (contains points and condenser), spark plugs and cables. The system has two circuits, a primary and secondary. The primary circuit has those units that carry only low voltage current. These units are the battery, ignition switch, ignition resistor (used with a 12-volt coil), primary winding in the coil, breaker points and condenser. The secondary circuit carries the current to the spark plugs after it has been increased to high voltage. This circuit includes such units as the secondary windings of the coil (fine windings), rotor, distributor cap, spark plugs, and spark plug cables.

Battery

The battery (and generator) furnish the source of voltage and current for the ignition system. Vehicles may be equipped with 6, 12, or 24-volt batteries. Twelve volt ignition systems are the most common in use today.

Ammeter and Ignition Switch

The ammeter, if present, is connected between the battery and the ignition switch. Although it is not essential to the

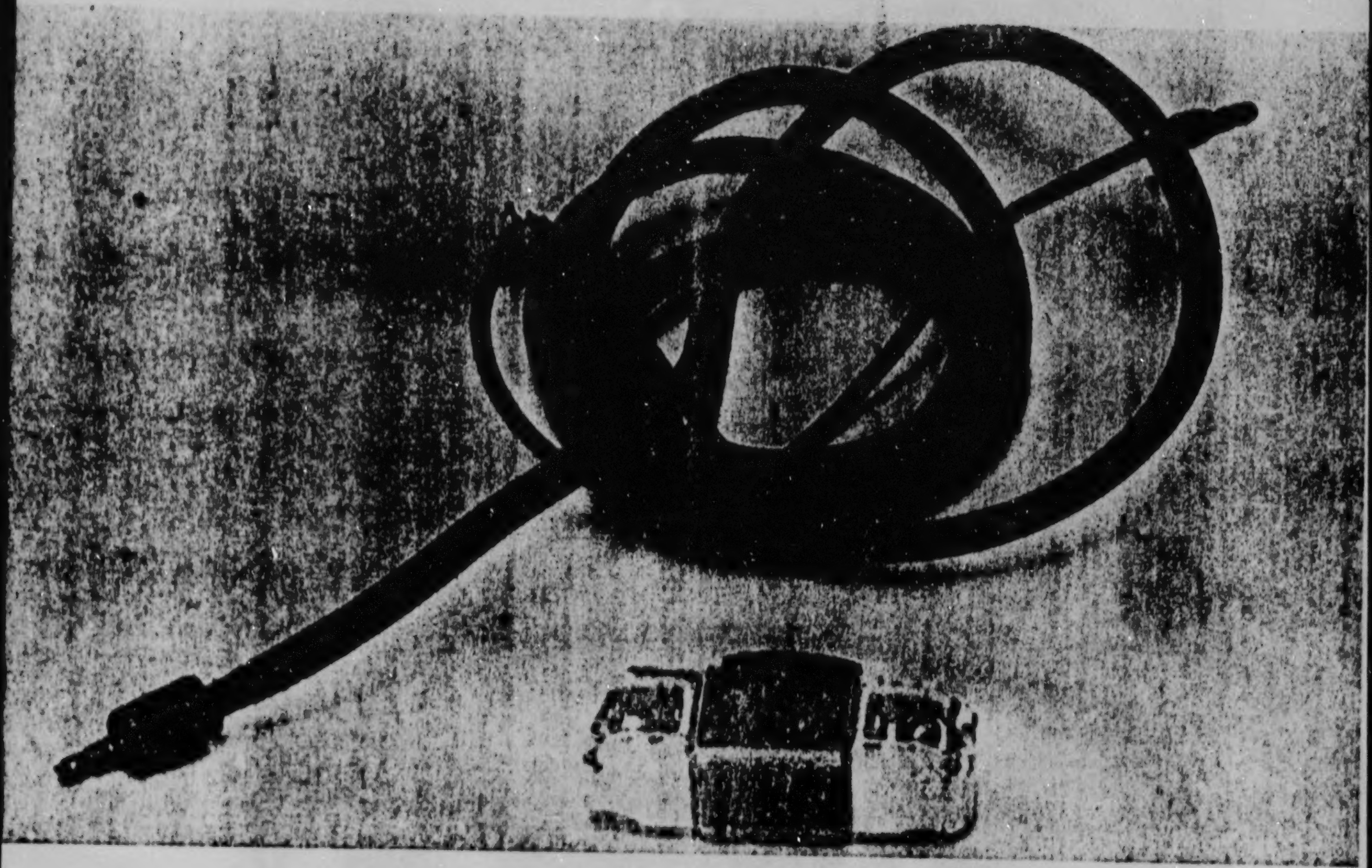

Figure 46. Ignition Resistors.

operation of the circuit, it is a unit which measures the flow of current in the vehicle electrical system. It is usually inserted to check the general condition of the system during operation. The ignition switch provides a means of opening and closing the primary circuit. Besides the ON-OFF position, many ignition switches have a START position which energizes the starting motor and ACCESSORY position which allows current to go to the accessories, but not through the ignition system.

Ignition Resistor

In a 12-volt ignition circuit, a ballast resistor, figure 46, or a resistor wire is connected in series with the coil primary windings to control ignition primary current. The resistor wire, as used on some applications, is of a certain size and of a certain length to cause the correct amount of resistance. The resistance in these systems changes very slightly with temperature. This prevents excessive primary current at low temperatures. It reduces the tendency for the distributor contact points to oxidize during cold weather. The ballast resistor, as used on other applications, is bypassed during cranking. The ignition coil is then connected directly to the battery. This allows for improved performance and easier starting. The bypassing on some units is done by use of a "finger" within the starter solenoid.

Ignition Coil

The ignition coil is a device which steps up (transforms) the low voltage of the battery or generator to a high voltage. This voltage may reach as much as 30,000 volts in some installations. The extreme high voltage is to provide the electrical pressure so that the electric current will jump the gap at the spark plugs. This ignites the compressed gasses in the cylinders of the engine. The ignition coil contains three essential parts. These are primary windings, secondary windings, and a soft iron core.

PRIMARY WINDINGS. These windings, figure 47, consists of a few hundred turns of relatively heavy wire.

SECONDARY WINDINGS. These windings, figure 47, consists of many thousands of turns of a very fine wire. It is assembled with the primary winding around the outside of it.

LAMINATED IRON CORE. The core, figure 47, is soft iron and is distributed so that one portion serves as a core for the windings. The remainder is a shell around the entire assembly.

CONSTRUCTION OF THE COIL. These parts of the coil are then placed in a case. The remaining space is filled with oil. The coil cap is then installed and sealed. This prevents the entrance of moisture, which would cause coil failure. It also helps in cooling the coil. Although there are a variety of ignition coils for various types of operation, figure 47 shows a typical ignition coil found on the vehicle.

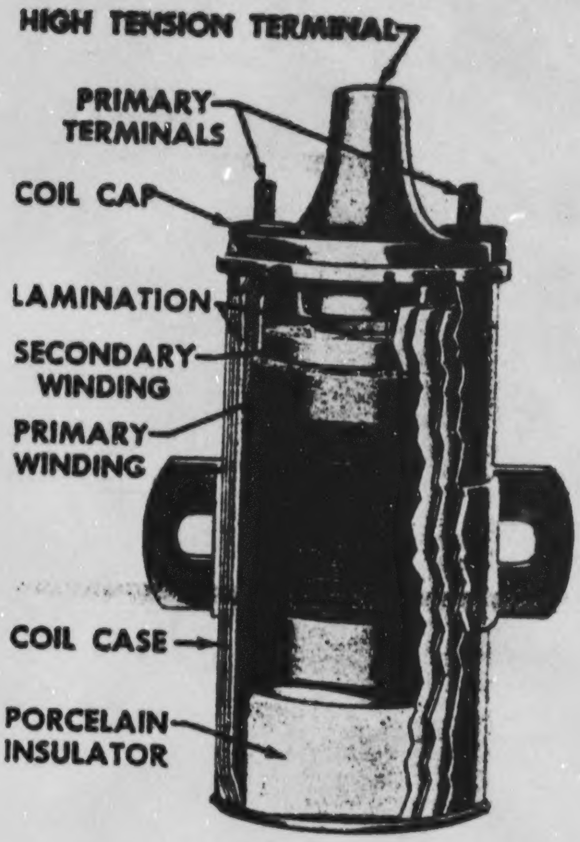
HIGH TENSION TERMINAL
PRIMARY TERMINALS
COIL CAP
LAMINATION
SECONDARY WINDING
PRIMARY WINDING
COIL CASE
PORCELAIN INSULATOR

Figure 47. Cutaway View of a Typical Ignition Coil.

THE COIL PRODUCES THE ZAP! The ignition coil operates on the principle of electromagnetic induction. When the primary circuit is closed, current from the battery or generator flows through the primary windings of the coil. This builds up a magnetic field around the coil primary windings. When the circuit breaks, the magnetic field collapses rapidly. The rapid movement of the collapsing lines of force induces a very high voltage into the secondary windings of the coil. (The amount will depend upon the construction of the coil, the number of turns of wire in each winding, and the amount of current flow through the windings.)

Ignition Distributor

The purpose of the distributor, figure 48, is to open and close the primary circuit by means of contact points. The distributor also directs the high voltage surge through the secondary circuit to the proper spark plug at the correct time. The distributor consists of a housing, shaft, breaker assembly, condenser, distributor cap and rotor, centrifugal advance mechanism and/or a vacuum advance mechanism.

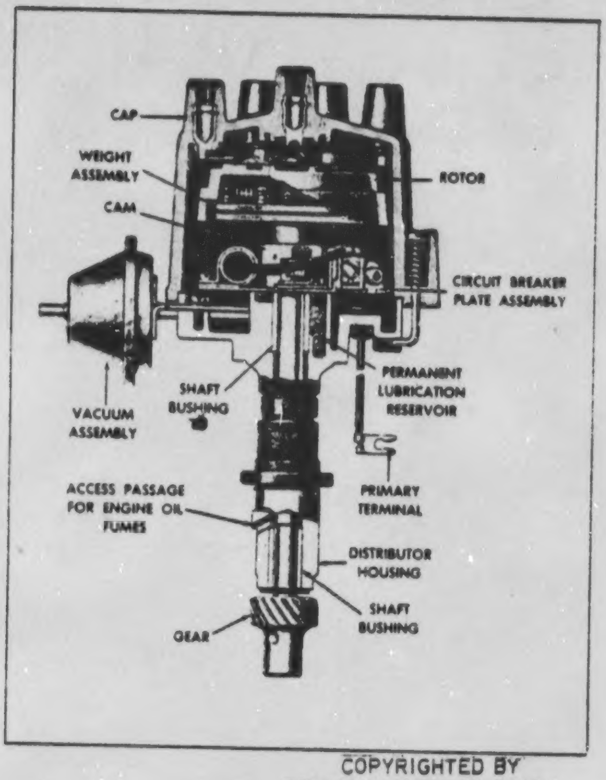
CAP
WEIGHT ASSEMBLY
CAM
ROTOR
CIRCUIT BREAKER PLATE ASSEMBLY
VACUUM ASSEMBLY
SHAFT BUSHING
PERMANENT LUBRICATION RESERVOIR
PRIMARY TERMINAL
ACCESS PASSAGE FOR ENGINE OIL FUMES
DISTRIBUTOR HOUSING
SHAFT BUSHING
GEAR

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Figure 48. Cross Section of Distributor.

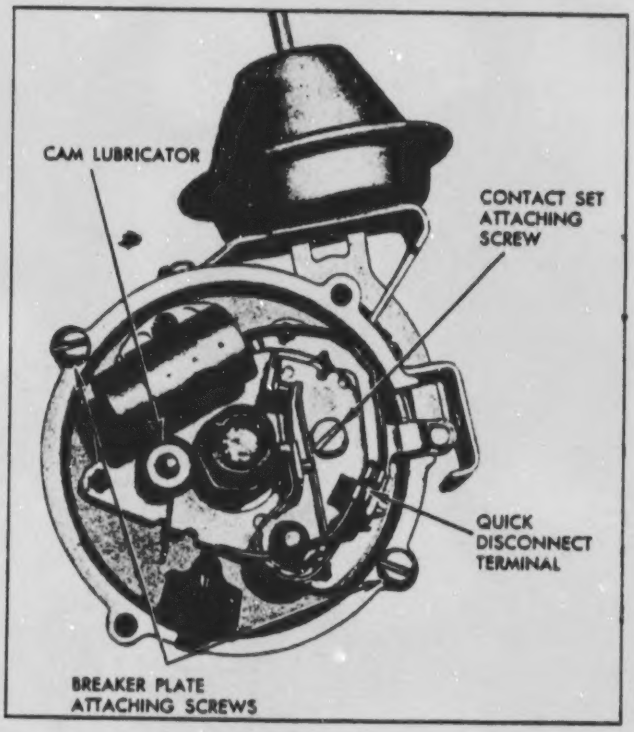

CAM LUBRICATOR
CONTACT SET ATTACHING SCREW
QUICK DISCONNECT TERMINAL
BREAKER PLATE ATTACHING SCREWS

Figure 49. Breaker Plate and Attaching Parts.

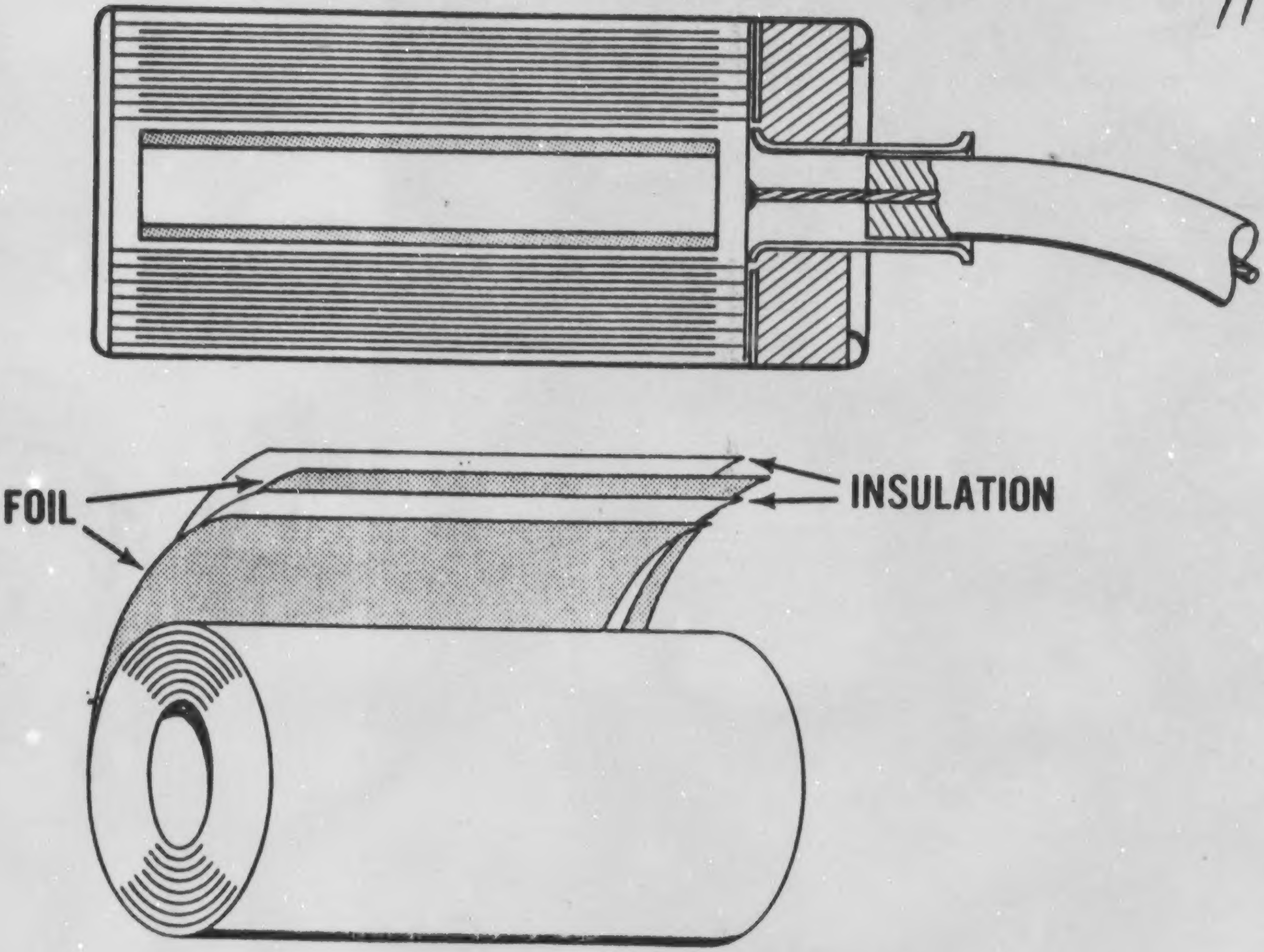
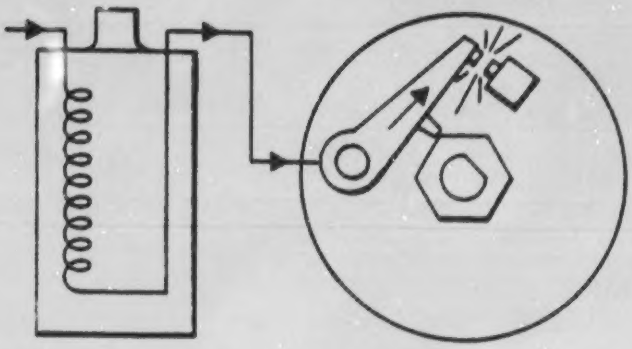
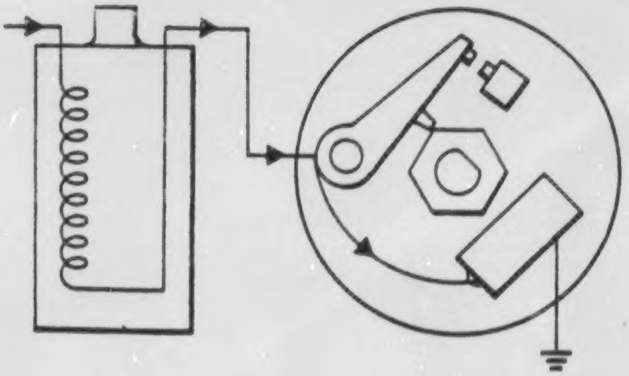

FOIL
INSULATION

Figure 50. Condenser Construction.



WHEN CONTACTS OPEN, CURRENT CONTINUES TO FLOW, CAUSING AN ARC ACROSS CONTACTS.

A - NO CONDENSER IN PRIMARY CIRCUIT



CONDENSER PROVIDES TEMPORARY PLACE FOR PRIMARY CURRENT TO GO, REDUCING ARCING AT CONTACTS.

B - WITH CONDENSER IN PRIMARY CIRCUIT

Figure 51. Consenser Action.

BREAKER ASSEMBLY, FIGURE 49. We said the coil operates on the principle of electromagnetic induction. There must be some means to open and close the primary circuit in order for high voltage to be induced into the secondary windings of the coil. The breaker points in the distributor provide this means. The assembly consists of the breaker plate, breaker points, contact support and condenser, figure 49. A breaker cam is driven by the engine. It is on the distributor shaft. The cam has lobes (the same number as there are cylinders in the engine). When the cam rotates, each lobe passes under the breaker point rubbing block. This separates the contact points. A high voltage surge is produced in the secondary winding of the coil. With every cam revolution, one spark will result for each cylinder of the engine. Remember that in a four-stroke cycle engine, each cylinder fires every other revolution. Therefore, on this type of engine the distributor shaft rotates at one-half the engine speed.

CONDENSER. The condenser in the primary ignition circuit prevents arcing at the distributor breaker points when they begin to open. This is because the condenser provides a place for current to flow until the points are safely separated. The action of the condenser requires special insulation between two foil sheets, figure 50. These foil sheets store current flow and bring it to a quick controlled stop, figure 51. Without the condenser, or if the condenser fails, no standard automotive ignition system would operate properly. The reason is that without some means of preventing arcing at the points, most of the energy in the coil would convert into current. This would flow across the points. This causes the points to burn and prevents the coil secondary winding from producing the high voltage surge required.

THE HIGH-VOLTAGE PORTION OF THE DISTRIBUTOR. The cap, rotor, and high tension leads carry the high voltage surges from the coil to the spark plugs. This must be done in the correct sequence. This part of the distributor is part of the secondary ignition system. The secondary circuit starts at the secondary winding of the coil. A high tension lead from the coil is connected to the center terminal of the distributor cap. From this point it continues through the cap to the rotor. The rotor is actually a revolving switch which rotates with the distributor shaft. It delivers electricity to the proper spark plug each time high voltage is induced into the secondary winding of the coil.

CENTRIFUGAL ADVANCE MECHANISM, FIGURE 52. In order for the engine to function properly, the ignition spark must occur at the proper cylinder at the exact time required. This is engine timing. We know that the ignition must be timed correctly when the engine is idling. When the engine is correctly timed, markings on either the engine flywheel or the crankshaft pulley must align with a stationary pointer at the instant that the plug in the number one cylinder fires. Correcting the timing is done by loosening and turning the distributor in its mounting.

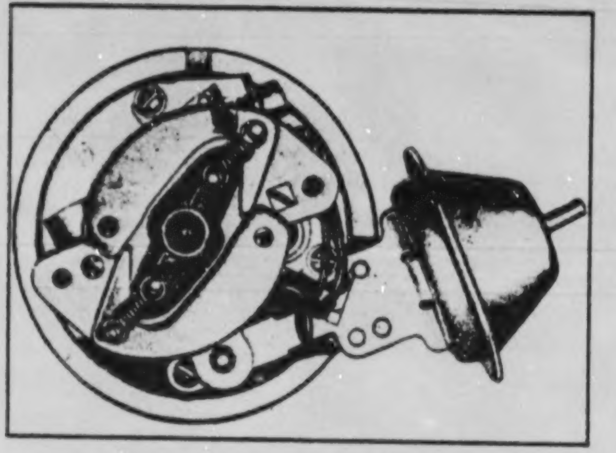


Figure 52. Advance Weights Installed.

However, the correct instant for introduction of the spark into the cylinder depends upon a number of different operating conditions such as different engine speeds and loads. For example, the spark must enter the cylinder earlier at high engine speeds so that the mixture can ignite and deliver its power to the piston. Therefore some type of device must be installed to vary the spark timing for different engine operating conditions. There are different types of devices used to vary the spark timing. The centrifugal advance mechanism, figure 52, advances the timing at high speeds. This type of advance consists of two weights that throw out against spring tension as engine speed increases. As engine speed increases, the breaker cam is caused to move ahead or rotate with respect to the distributor shaft. This causes the cam to open and close the breaker points earlier at high speeds. This type of advance operates entirely by engine speed. It will advance a certain amount at any speed above idle. The timing of the spark to the cylinder varies from no advance at low speeds to full advance at high speeds.

VACUUM ADVANCE MECHANISM, FIGURE 53. Consider conditions other than just engine speed to time the spark at the cylinder. Although the centrifugal advance mechanism operates entirely by engine speed, and will advance a certain amount at any particular speed above idle, there are times when additional spark advance is required which cannot be furnished by this device. For example, many times a spark advance must be based on the engine intake manifold vacuum. To provide for this, a vacuum advance mechanism, figure 53, is installed. There are types which are installed to rotate the distributor housing (in this type the housing must be free to rotate in its mounting). Other types rotate the breaker plate only with respect to the remainder of the distributor. This type moves the breaker point against the direction of shaft rotation so that the rubbing block meets the cam earlier in the cycle to provide advance timing.

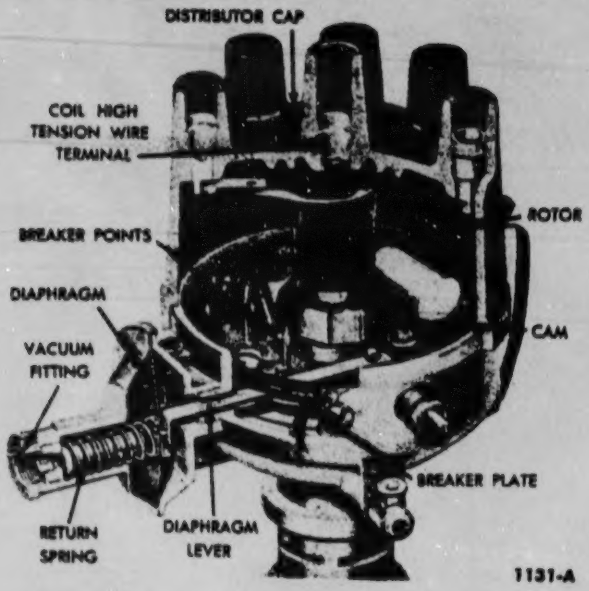


Figure 53. Vacuum Advance Mechanism.

The vacuum advance mechanism consists of a spring loaded diaphragm connected by linkage to the distributor housing or breaker plate. The spring loaded side of the diaphragm is airtight. It is connected by a vacuum passage to an opening in the carburetor. Because of the position of the opening in the carburetor, when the throttle is in the idle position no vacuum is in the passage. However, when the throttle is moved to part throttle position, it swings past the opening of the vacuum passage. Intake manifold vacuum can then draw air from the airtight chamber and cause the diaphragm to be moved against the spring. When this occurs, the motion of the diaphragm causes the distributor to rotate in its mounting or the breaker plate to rotate (whichever the vacuum advance operates), and the contact points are carried around the cam to the advanced position. Spring tension will return the mehcanism to no advance when the throttle is returned to the idle position.

The vacuum advance is a device which increases fuel economy at part throttle position only. It is very important that both of the advance mechanisms operate within the correct limits to insure the best engine operation under all conditions. On some later model engines, full vacuum advance at idle occurs. This is to improve the operation of the engine at idle. It is done by taking intake manifold vacuum off below the throttle plate. On this type of application the vacuum line to the vacuum advance mechanism must be disconnected when timing the ignition.

Ignition Wiring

Ignition wires used to connect the various parts of the ignition system are of two types. These are the primary and secondary wiring.

PRIMARY WIRING. The primary circuit is designed for low resistance combined with good mechanical strength. It usually is a large conductor and has oil and abrasive resistant covering.

SECONDARY WIRING. The high tension wiring, such as spark plug leads, can be a smaller conductor. It must have heavy insulation to prevent leakage of high voltage. The wires must be able to withstand heat, vibration, abrasion and oil. If water or dust enters any crack in the insulation, an electrical path is formed. This partially grounds the high tension voltage and the spark at the plugs will be weak.

TVRS Wiring. Automotive ignition systems during operation produce certain high frequency electrical signals. These signals can interfer with the car radio and nearby television reception. Practically all ignition systems, therefore, incorporate some form of resistance of suppression to eliminate this undesirable interference. One of the most common methods of suppression is the use of secondary ignition suppressor cable. It is commonly called TVRS cable (television-radio suppression). TVRS cable consists of a braided linen nylon core impregnated with carbon to form a conductor. Wire pins are used to connect the resistor cable core to the terminals. This type cable requires good service procedures so as not to damage the cable.

Spark Plugs

The only purpose of the spark plug is to create a spark to ignite the air-fuel mixture in the cylinder of the engine. If the spark plug does not function as required, all other units in the ignition system will have worked for no purpose. The spark plug must be able to function properly under many various conditions. The plug must also be able to withstand repeated terrific combustion pressures.

CONSTRUCTION OF THE SPARK PLUG. The spark plug, figure 54 consists of the shell assembly, core insulator assembly, terminal, upper sealing gasket, lower sealing gasket, center electrode and ground or the side electrode. It fits into the cylinder head. The two electrodes, separated by an air gap, create a spark between them for combustion.

SPARK PLUG HEAT RANGE. The term "heat range" refers to the classification of spark plugs according to their ability to transfer heat from the firing end of the plug to the cooling system of the engine. Varying temperatures in the combustion chambers of different engines make spark plugs of different heat ranges necessary. The rate of heat transfer is controlled mainly by the distance between the gasket seat and the insulator tip, figure 55. You must select the proper heat range when replacing spark plugs in the vehicle.

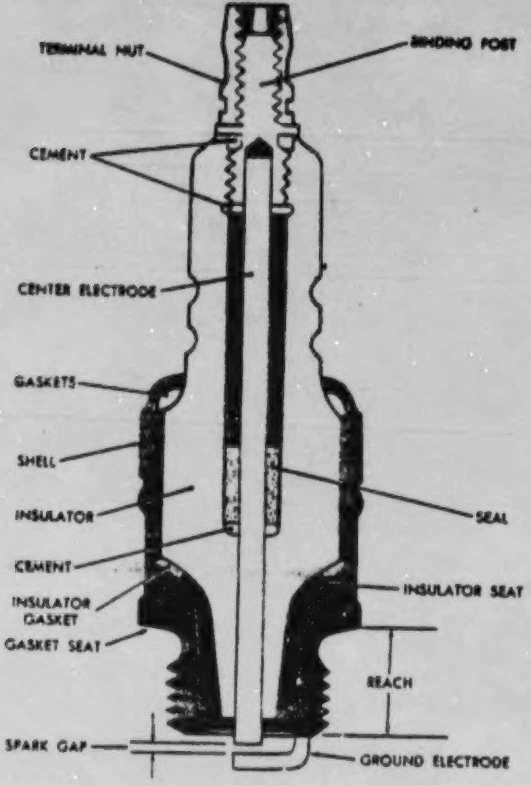

TERMINAL NUT
BINDING POST
CEMENT
CENTER ELECTRODE
GASKETS
SHELL
INSULATOR
SEAL
CEMENT
INSULATOR SEAT
INSULATOR GASKET
GASKET SEAT
REACH
SPARK GAP
GROUND ELECTRODE

Figure 54. Typical Spark Plug Cutaway View.

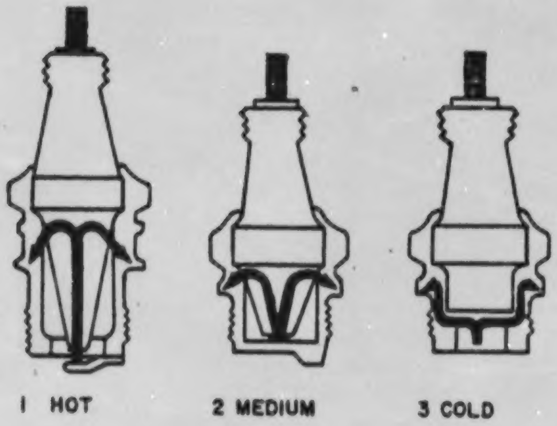

1 HOT
2 MEDIUM
3 COLD

Figure 55. Heat Ranges of Spark Plugs.

THREAD SIZE AND REACH. Plugs are also designed in several thread sizes and "reaches," figure 54. Thread reach is the distance between the gasket seat and the end of the shell. Thread size is the diameter of the threads measured in millimeters.

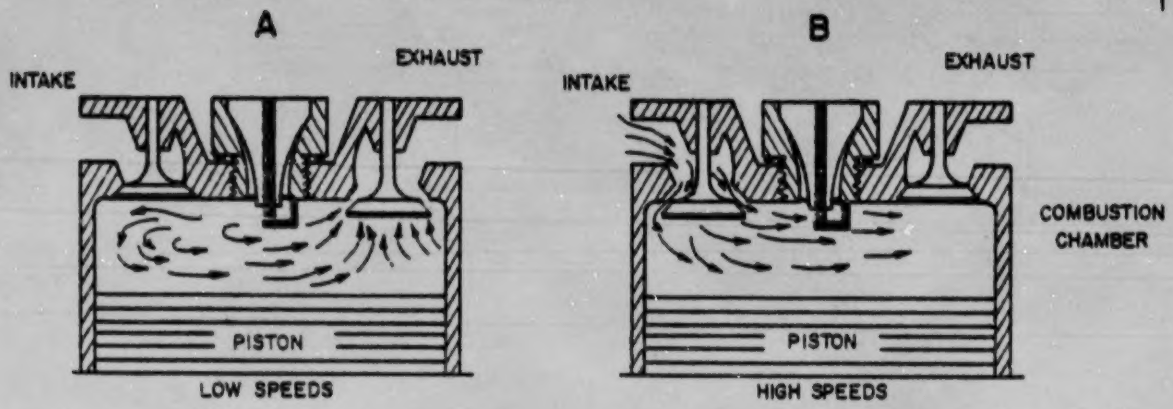
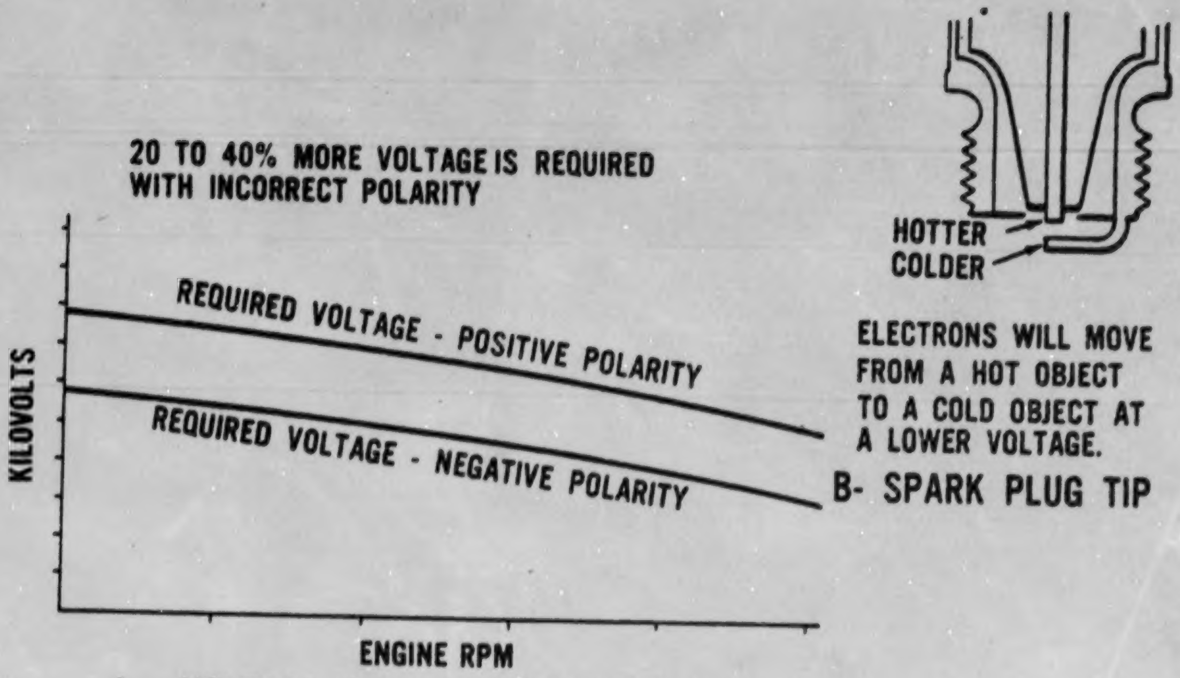


Figure 56. Power Tip Plug In Combustion Chamber.

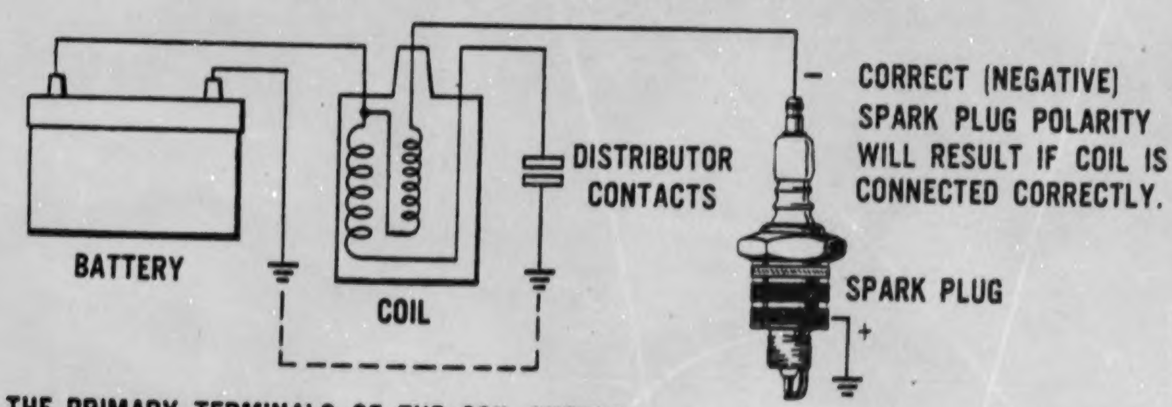
POWER TIP PLUGS. Power tip plugs are designed to deliver peak performance and economy in high horsepower engines at all speeds. They are original equipment in many leading makes of automobiles. On this type of plug, the insulator tip protrudes farther into the combustion chamber, figure 56. At low speeds, the projecting tip is in the thick of combustion as shown in A, figure 56. There it gets hotter quicker, and stays hot to burn fouling deposits away clean. At high speeds the projecting tip is in the path of incoming air-fuel mixture, as shown in B, figure 56. There it stays cooler to effectively check any damaging preignition. This type of plug actually serves as both a hot and a cold plug.

VOLTAGE AT SPARK PLUG TERMINALS, FIGURE 57. The direction of current flow through the coil has not been studied yet. It must be discussed briefly now. One of the major causes for the engine to be hardstarting or spark plugs to misfire under a load is reversed current flow through the coil. This is called reversed coil polarity. It results from hooking the ignition coil lead wire of the distributor to the wrong side of the coil. Voltage at the spark plug terminals should always be negative. Whether it is or not depends on how the primary leads are attached to the coil. If positive voltage is supplied to the spark plug terminals, it would take more voltage to make current jump the gap between the electrodes as shown in A, figure 57. Remember that electric current is the flow of electrons from negative to positive. Electrons will move from a hot center electrode to a colder ground electrode at a lower voltage, as shown in B, figure 57. With incorrect polarity, the hotter center electrode becomes positively charged. Therefore, electrons must now leave the negative charged electrode, the ground electrode, which is cooler, and move to the positive charged electrode, the center electrode. This requires a higher voltage. The primary terminals of the coil should be connected so that the polarity markings correspond to the polarity of the battery, as shown in C, figure 57. For a negative ground system, the + terminal of the coil is connected to the battery side of the ignition system and the - terminal to the distributor side.



A - VOLTAGE REQUIRED AT SPARK PLUG

B- SPARK PLUG TIP


BATTERY
COIL
DISTRIBUTOR CONTACTS
-
CORRECT (NEGATIVE) SPARK PLUG POLARITY WILL RESULT IF COIL IS CONNECTED CORRECTLY.
SPARK PLUG
+

THE PRIMARY TERMINALS OF THE COIL SHOULD BE CONNECTED SO THAT THE POLARITY MARKINGS CORRESPOND TO THE POLARITY OF THE BATTERY.

C - CORRECT COIL CONNECTIONS

Figure 57. Coil Polarity.

Summary

At this time a brief summary of how the ignition system operates will be given. As already stated, the battery or generator furnishes the source of voltage and current for the ignition system. When the contact points in the distributor are closed, the ignition coil primary winding is connected to the battery or generator. At this time a magnetic field builds up within the coil. As the contact points open (they are opened and closed by a rotating cam on the distributor shaft), the magnetic field collapses and sends a high voltage surge into the secondary circuit. This surge must then be directed to the spark plug in the cylinder ready to fire. This is done by the distributor cap and rotor. Other devices are installed in the ignition system for proper operation. These are the condenser, ignition resistor, ignition switch and ammeter. The ignition system would not function properly without a condenser. The condenser is connected across the contact points to provide a place for current to flow until the contact points are safely separated. This prevents arcing at the contact points. An ignition resistor is installed in the ignition system to improve ignition performance. The ignition switch provides a means of manually opening and closing the primary circuit. The ammeter measures the flow of current in the vehicle electrical circuit.

> Note: Ignition systems may vary in design and construction of the various components. The operating principle is the same for all battery ignition systems.

SERVICING THE BATTERY SYSTEM COMPONENTS

The spark that ignites the fuel-air mixture in the cylinder must do so at the exact time with just the right voltage. This spark does not just appear. It occurs because electricity goes to a coil which converts low voltage to high voltage. A timing device (distributor) then directs the spark to the right spark plug at the exact instant required in the cylinder. Because of the exacting nature of the ignition system, the system must be inspected, tested and serviced regularly to maintain this near perfect action.

Inspections

Periodic inspections must be made to determine the extent of wear or deterioration. Operating conditions will determine the extent of wear or deterioration. Operating conditions will determine the time that inspections will be made. For example, dust and moisture may cause excessive wear. The best assurance of obtaining the maximum service with the minimum trouble from ignition systems is to follow a regular inspection and maintenance procedure. Inspection of the contact points, advance mechanisms, connections and cables, distributor cap and rotor, is very essential. The contact points should be examined for burned or oxidized and pitted conditions. High tension wiring should be checked for the condition of the insulation and cleanliness. The distributor cap, rotor, and coil high tension terminal should be examined for carbon paths, dirt, or moisture. Dirt and moisture should be wiped off.

Distributor Lubrication

The distributor requires lubrication at specific time intervals. The distributor shaft is lubricated by a variety of methods. Always refer to the applicable publications for lubricating procedures. The breaker cam is also lubricated in a variety of ways and the lubrication procedures used as given by the manufacturer.

> Note: Avoid excessive lubrication. If too much oil is used, the excess may get on the contact points and cause rapid burning of points. This is one of the most common causes of contact point failure.

Reasons for Ignition System Failures

Ignition system failures can be grouped into three categories. The three categories are as follows: loss of energy in the primary circuit, loss of energy in the secondary circuit, and out of time.

PRIMARY SYSTEM FAILURE. There are several conditions which may cause this failure. It may be due to defective leads, bad connections, burned contact points or switch, or an open coil primary. Also, it may be caused by a discharged battery; defective generator; points improperly set; defective condenser; or a grounded primary circuit in the coil, wiring, or distributor.

SECONDARY SYSTEM FAILURE. This category may also have several conditions which may cause the failure. Fouled, broken or improperly adjusted spark plugs will cause secondary system failure. Also, high tension leakage, caused by such items as defective wiring, coil head, distributor cap, rotor and connections will cause secondary system failure.

TIMING. The timing may be affected by not being set properly, worn distributor shaft or bearing, distributor shaft bent, defective vacuum advance, defective centrifugal advance, plugs of the wrong heat range or fouled plugs. While the plugs have nothing to do with timing, they may cause preignition.

TEST EQUIPMENT FOR TESTING IGNITION SYSTEM COMPONENTS

Because of the effect that an improper functioning ignition system has on the operation of the engine and the exacting nature of the ignition system, test instruments should be used when servicing the ignition system. Even though ignition system failures are grouped into three categories, and certain checks can be made to isolate the trouble without the use of test equipment, certain ignition system units should be checked periodically with the use of test equipment to determine if they are functioning properly.

Testing the System Using an Oscilloscope

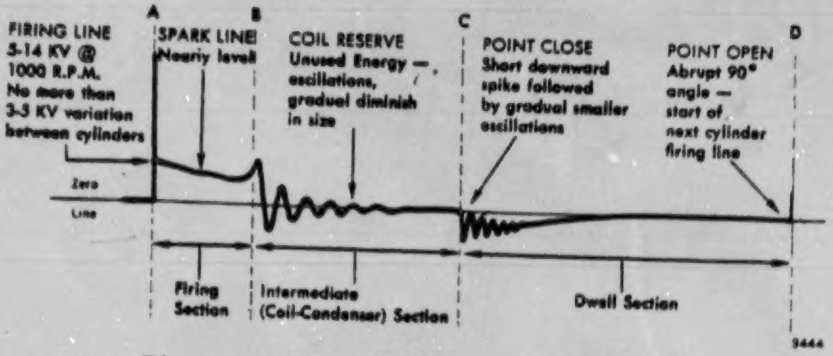

A
B
C
D
FIRING LINE
5-14 KV @
1000 R.P.M.
No more than
3-5 KV variation
between cylinders
SPARK LINE
Nearly level
COIL RESERVE
Unused Energy —
oscillations,
gradual diminish
in size
POINT CLOSE
Short downward
spike followed
by gradual smaller
oscillations
POINT OPEN
Abrupt 90°
angle —
start of
next cylinder
firing line
Zero
Line
Firing
Section
Intermediate
(Coil-Condenser) Section
Dwell Section
9444

Figure 58. Typical Normal Operating Ignition System Cycle.

The oscilloscope basically pictures on a viewing screen the ignition system voltage compared to time. Repetitive cycles, as occur in the ignition system with each firing of the spark plug, are traced on a screen in the form of a pattern. If the basic pattern, figure 58, is known, any deviation from this pattern can indicate malfunctions in the system. The oscilloscope, therefore, is used as an excellent diagnostic tool to spot troubles that are occurring within the ignition system. The oscilloscope method of circuit checking has proven to be a quick, highly reliable method of determining ignition system problems and their cause. Since many different models of oscilloscopes are made, your instructor will give you another study guide/workbook on the particular model that you will use in this block of instruction.

Testing the Distributor

When looking for causes of trouble, the distributor is the heart of the engine. It must have careful and minute inspection. There are several fundamental tests which must be made on a distributor to find if it is properly performing its job. The distributor is removed from the engine for certain tests. Some tests can be made with the distributor installed on the engine. There are several different makes and models of distributors. Therefore, the information concerning the tests and the methods of making the tests must be very general in nature. When a distributor is being serviced, refer to the factory procedures and specifications for the specific distributor.

ADVANCE MECHANISM. Although the advance mechanisms can be checked for freeness by turning the breaker cam by hand in the direction of rotation and then releasing it, this only checks for freeness. It does not give information on the way in which it operates. To obtain this information, the distributor must be removed from the engine and checked on the distributor tester. The tester is a device in which the speed of the rotation of the distributor shaft can be exactly controlled for testing the centrifugal advance, which reacts to speed only. For testing the vacuum advance mechanism, the tester must have a vacuum advance tester where a source of vacuum can be applied to the vacuum advance mechanism. These two advance mechanisms are carefully checked against manufacturer's specifications to find if the proper advance curve under all operating conditions is obtained.

Note: For proper procedures used in testing, always refer to the applicable publications.

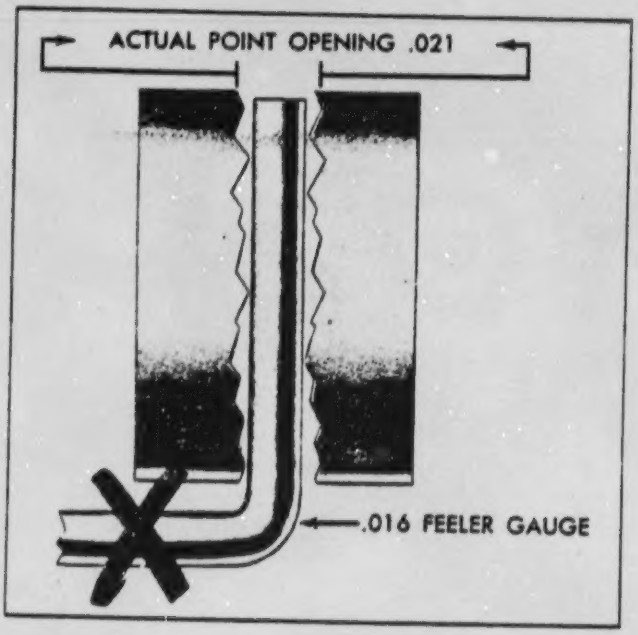


Figure 59. Inaccurate Gauging of Rough Points.

CONTACT POINT ADJUSTMENT. There are different methods of checking point openings. New points can be checked with a wire gage. Never use a flat feeler gauge, especially on old points. Using a wire gage eliminates the possibility of an incorrect gap because of rough points, figure 59. Point openings, new or old, can be checked with a dwell meter. These methods are used with the distributor in the vehicle. However, a preferred method of checking point opening of used contact points is by placing the distributor in the distributor tester. With the distributor installed in the tester, attach the dwell meter correctly. Adjust the contact points either by loosening the lock screw and turning the eccentric screw, figure 60, or by using a "hex" type wrench to turn the adjusting screw, figure 61, to specified limits. The advantage of using a distributor tester is that it not only measures cam angle or dwell, but it also uncovers irregularities between cam

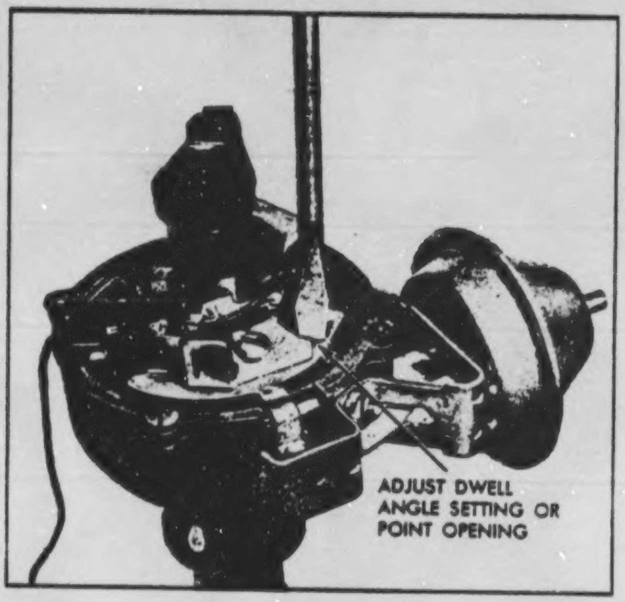
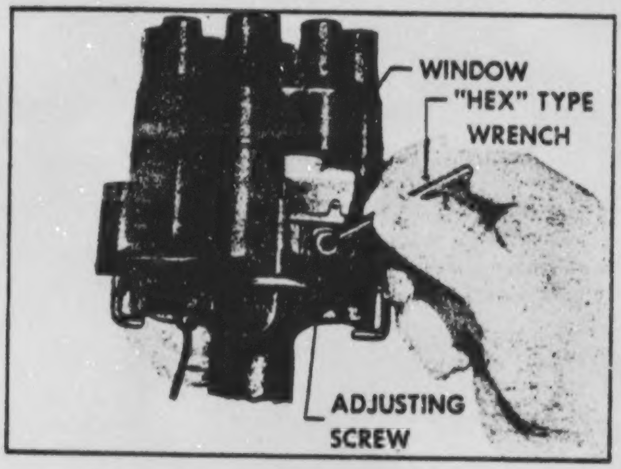

ADJUST DWELL
ANGLE SETTING OR
POINT OPENING

Figure 60. Setting Point Opening.


WINDOW
"HEX" TYPE
WRENCH
ADJUSTING
SCREW

Adjusting Dwell Angle

Figure 61. Adjusting Dwell Angle.

lobes, point bounce, alignment of rubbing block with cam, alignment of contacts and breaker arm spring tension.

CONTACT POINT DWELL. Dwell is the period during which the distributor points remain closed for each ignition cycle. The dwell meter electrically measures this period and registers the average for each cylinder in terms of degrees of distributor cam rotation. The total number of degrees for each ignition cycle is 360 degrees divided by the number of cylinders.

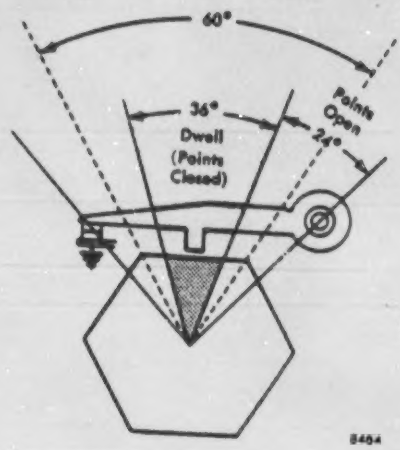

60°
36°
Dwell
(Points
Closed)
Points
Open
24°
8464

Figure 62. Point Dwell - Six Cylinder Shown.

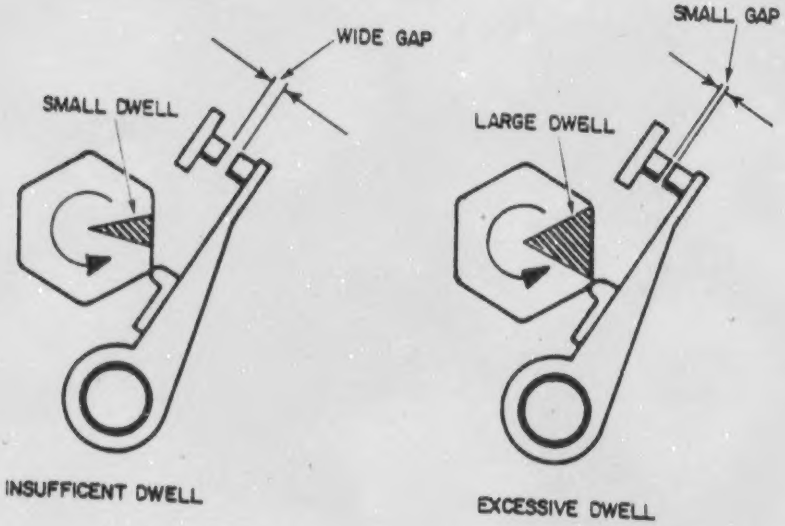

WIDE GAP
SMALL DWELL
SMALL GAP
LARGE DWELL
INSUFFICENT DWELL
EXCESSIVE DWELL

Figure 63. Effects of Point Gap On Dwell.

Figure 62 shows 60 degrees (between dotted lines) for each cylinder of a six cylinder engine and 36 degrees (the shaded area) as the dwell. Figure 63 shows that a wider point setting will result in less dwell and a closer point setting will increase dwell. If the dwell reading is not to specifications, the trouble could be incorrect point spacing, defective point rubbing block or breaker arm, misaligned or worn distributor cam.

DWELL VARIATION. Dwell variation is determined by noting any dwell change as the engine is operated at different speeds. Excessive variation indicates a change in point opening that can result from shaft or bushing wear or looseness. Generally speaking, dwell should not vary more than three degrees between idle speed and 1,750 RPM. If dwell variation is more than three degrees, the distributor should then be checked more thoroughly on the distributor tester.

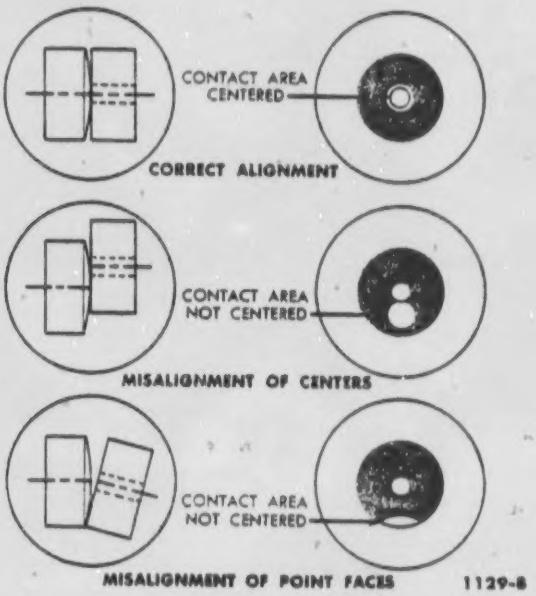

CONTACT AREA CENTERED
CORRECT ALIGNMENT
CONTACT AREA NOT CENTERED
MISALIGNMENT OF CENTERS
CONTACT AREA NOT CENTERED
MISALIGNMENT OF POINT FACES
1129-B

Figure 64. Breaker Point Alignment.

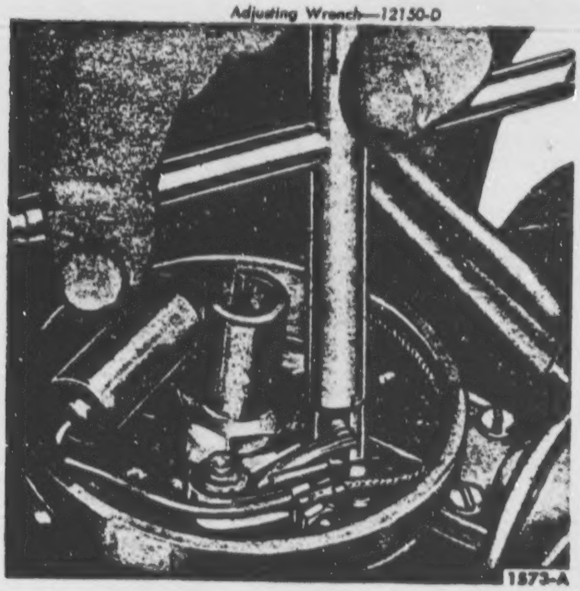

Adjusting Wrench—12150-D
1573-A

Figure 65. Aligning Breaker Points.

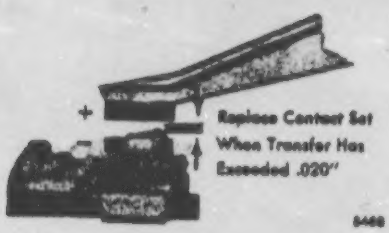

+
−
Replace Contact Set
When Transfer Has
Exceeded .020"
6468

Figure 66. Contact Point Material Transfer.

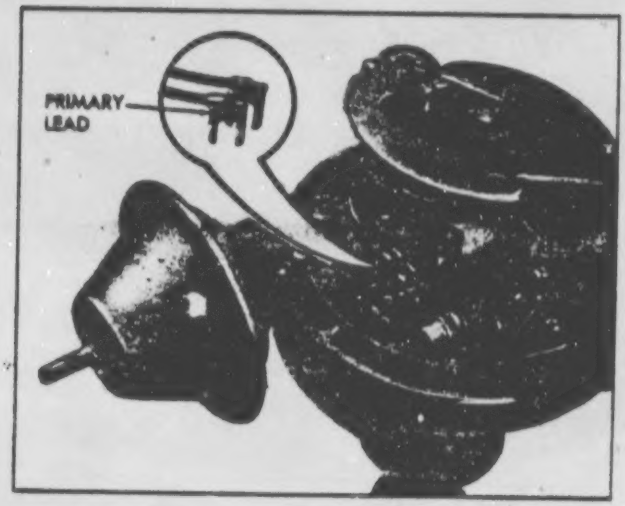

PRIMARY
LEAD

Figure 67. Distributor Lead Arrangements.

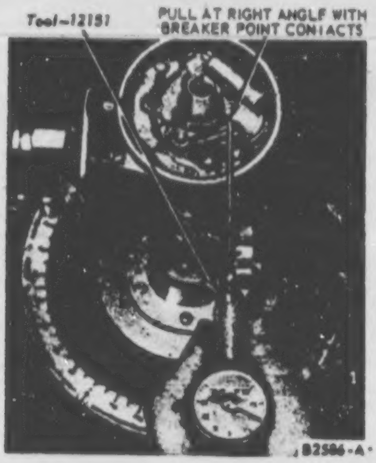

Tool-12151
PULL AT RIGHT ANGLE WITH
BREAKER POINT CONTACTS
B2586-A

Figure 68. Checking Breaker Point Spring Tension.

CONTACT POINT ALIGNMENT AND REPLACEMENT. The contact point set is replaced as a complete assembly. The service replacement contact set has the breaker lever spring and point alignment preadjusted at the factory. Normally, only the dwell angle (point opening) requires adjustment after replacement. However, in some cases the points may require alignment. Contact point surfaces must meet squarely, figure 64. Use a point aligning tool to align the point contact surfaces, figure 65, if necessary. Correct alignment by bending the fixed contact support only. Never bend the breaker lever! Rough contacts which are greyish in color have a greater area of contact than new contacts; and will provide satisfactory service until most of the tungsten is worn off. Pitted or transferred contacts is a normal condition and should not necessarily be replaced unless the transfer of metal has exceeded .020 inches, figure 66.

> Caution: On some makes of distributors, be sure to observe the location of condenser lead, primary lead, and the plate ground lead, figure 67. Leads must be properly located to eliminate lead interference between cap, weight base, and breaker advance plate.

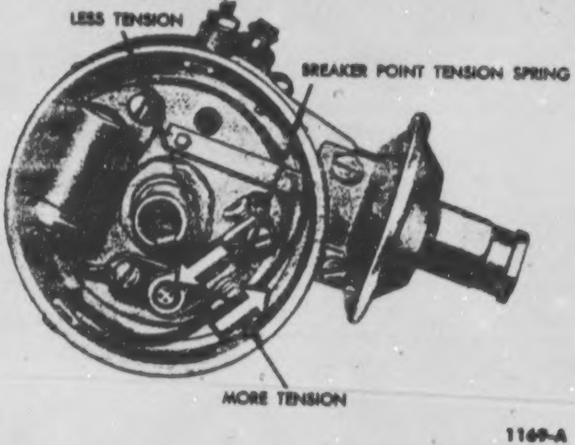
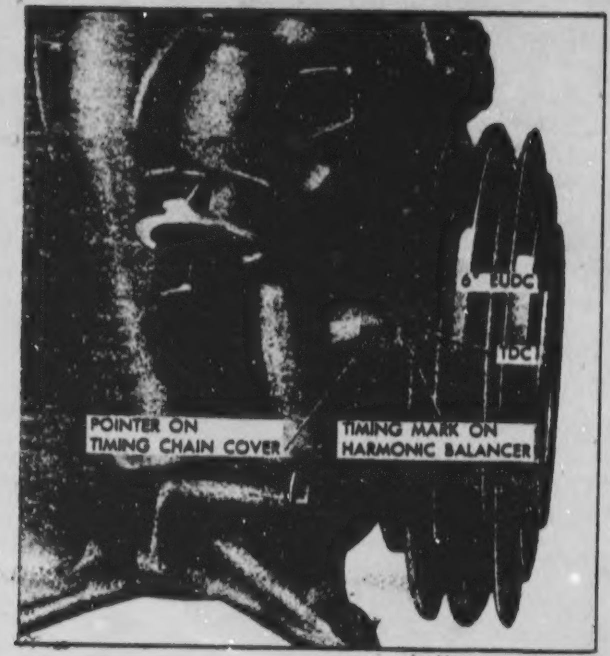


Figure 69. Adjusting Breaker Point Spring Tension.

BREAKER POINT SPRING TENSION. The contact point pressure is checked with a spring gage, figure 68. Excessive spring pressure causes rapid rubbing block, cam, and point wear. Too weak a spring will permit high speed point bounce and cause arcing and burning of the points. Note this condition when using the tester and observing the firing pattern at different speeds. When making this check, the spring gage should be hooked to the breaker moveable point. Exert the pull at an angle of 90° with the point surface. Make the reading just as the points separate. Different types of breaker points will require different tensions. Always refer to factory specifications. If the tension is not within specifications, loosen the screw that holds the end of the spring and slide the spring end in or out as necessary, figure 69. Tighten the screw and recheck spring tension.

> Note: Always check the spring tension of all new points when installed.


6° BTDC
TDC
POINTER ON TIMING CHAIN COVER
TIMING MARK ON HARMONIC BALANCER

COPYRIGHTED BY
PONTIAC MOTOR DIVISION

Figure 70. Timing Marks and Pointer.

IGNITION TIMING. In a previous lesson the timing of an engine was discussed. The engine must be timed so that a spark reaches the cylinder that is supposed to fire at the exact time. For this the contact points must be timed to open and close in proper relation to the piston positions in the cylinders. The previous lesson explained the different timing procedures. For example, many engines have a mark on the flywheel or dynamic balancer which aligns with a stationary pointer when number 1 cylinder is ready to fire, figure 70. At this instant, the contact points should separate. Various methods of checking the position of the points at this time are used. A test lamp hooked across the points will indicate this. Loosen the distributor in its mounting and rotate the distributor until the points just open with engine positioned properly. Another method is by using an ignition timing light. The power for the light is obtained from the engine battery or a 110-volt source, depending upon the light being used. The light flashes are triggered by the number 1 spark plug. With the engine running, the light flashes make the flywheel or pulley seem to be stationary. This allows for the timing to be observed. Engines using the vacuum advance must have the vacuum line disconnected when checking the timing. Correct timing by rotating the distributor in its mounting the same as when the light was used.

Ignition Coil Tests

Coil testers are available in most repair and testing shops. Whenever coil performance is suspected as the cause of trouble, the coil should be tested according to manufacturer's recommendation.

A coil secondary continuity test is made to check for opens, shorts, or excessive resistance in the secondary windings of the coil. A coil capacity test determines whether or not the coil has sufficient output.

Ignition Condenser Tests

To test the condenser, a good condenser tester must be used. A good condenser tester should be able to test the condenser for insulation breakdown, low insulation resistance, high series resistance and capacity. These conditions will all affect ignition performance. The procedures for making these tests are covered in the applicable publications. Because of the different types of test equipment, it is very important to refer to the applicable factory manuals for these procedures.

Spark Plug Cleaning and Testing

It has been mentioned previously just how important the proper plug and its condition is for the efficient operation of the engine. It will also be shown in a later lesson how the plug condition will indicate different troubles within the engine. Therefore, remember that the inspection, cleaning, and testing procedures are very important.

REMOVING SPARK PLUGS. In most cases, the correct procedure for removing the plugs is not thought of too seriously. However, being careless when removing the plugs may cause serious troubles. After the ignition wiring has been removed, select the proper size deep socket. Improper wrenches are often the cause of spark plug insulator breakage. The plugs should each be loosened two complete turns. This action will loosen any dirt around the base of the plug. Use a blast of compressed air to remove this dirt to prevent it from falling into the combustion chamber when the plug is removed.

> Note: Place each spark plug in a suitable holder in the order of removal.

VISUAL INSPECTION OF SPARK PLUGS. The plugs should be checked for cracked insulators, worn electrodes, etc. The plug gasket should be checked. If it is not compressed, it could mean that the plug was not properly tightened when installed. This could cause excessive burning of the electrodes and overheating of the insulator tip. If the gasket is distorted, the plug has been tightened too tightly. This may cause strain on the steel shell. The gasket should be approximately one-half compressed and show a clean, even surface. The spark plug when operated under normal conditions should have only a few deposits which will be light tan or grey in color. The electrodes will not be burned. The gap should not show a growth of more than about 0.001" per 1,000 miles of operation. The spark plug may have several appearances which are caused by different troubles in the engine.

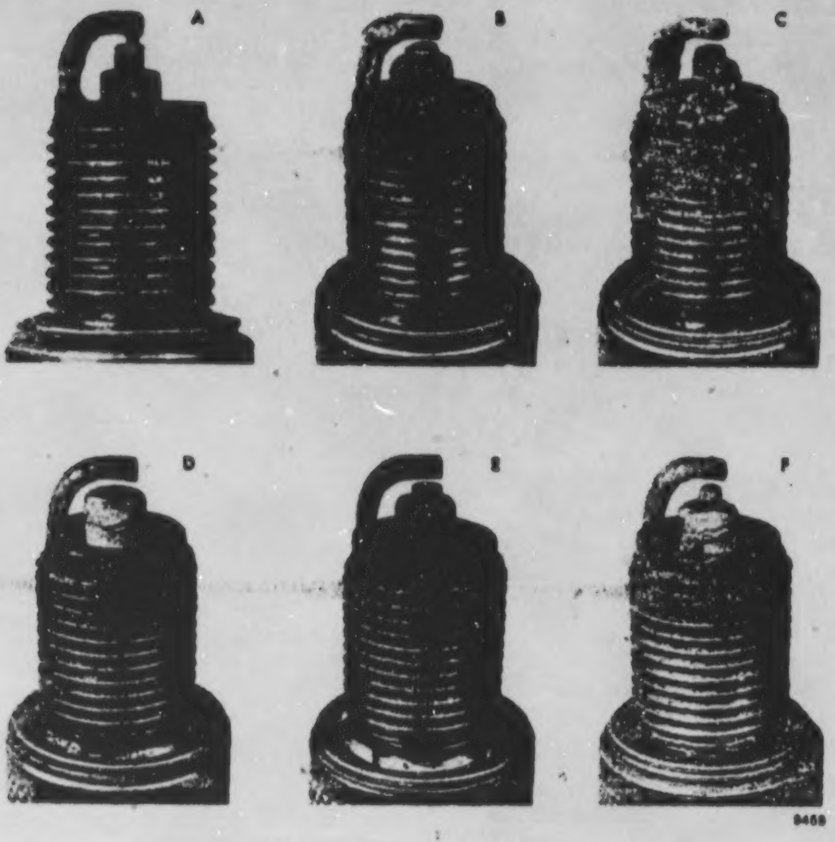


Figure 71. Spark Plug Conditions.

Gap Bridging. Gap bridging, figure 71(A), may be traced to flying deposits in the combustion chamber. In a few cases, fluffy deposits may accumulate on the plugs during intown driving. When the engine is suddenly put under load, this material can melt and bridge the gap.

Scavenger Deposits. Fuel scavenger deposits shown in figure 71(B) may be white or yellow in color. This may appear to be harmful, but this is a normal appearance with certain brand fuels. Such materials are designed to change the chemical nature of deposits to lesson misfire tendencies. Notice that accumulation on the ground electrode and shell areas may be unusually heavy, but the material is easily cleaned off. Such plugs are normal in condition and can be cleaned with standard procedures.

Chipped Insulator. This condition is shown in figure 71(C). It usually results from bending the center electrode during regapping of the plug. Under certain conditions, severe detonation can also split the insulator firing end. The plug must be replaced.

Preignition Damage. Preignition damage, figure 71(D) is caused by excessive temperatures. They produce melting of the center electrode and, somewhat later, the ground electrode. Insulators will appear relatively clean of deposits. Check for correct plug heat range, over-advanced ignition timing and similar reasons for overheating.

Cold Fouling. Cold fouling, or carbon fouling, figure 71(E), shows dry, black appearance of one or two plugs in a set. Check for sticking valves or bad ignition leads. Fouling of the entire set may be caused by a clogged air cleaner, a sticking exhaust manifold heat valve, or a faulty choke.

Overheating. Overheating, figure 71(F), is indicated by a dead white or grey insulator which appears "blistered." Electrode gap wear rate will be considerably in excess of 0.001" per 1,000 miles. This may suggest that a cooler heat range should be used. However, over-advanced ignition timing, detonation and cooling system stoppages can also overheat the correct spark plug.

CLEANING THE SPARK PLUG. Remove the old gasket before cleaning. If the plug has an oily deposit on the firing end, it should always be degreased before cleaning with abrasive in a plug cleaner. Degrease the plug by using suitable solvent. Then dry. When the plug is prepared for cleaning, the plug should be placed in the cleaner adapter of the correct size. The abrasive blast should be applied. Wobble the top of the plug in a circle while applying the blast. This will properly clean the insulator tip and electrodes. The extent of cleaning time should be only that which is necessary to clean off the deposits on the insulator nose. Use an air blast to remove the abrasive remaining inside of the firing end. The threads should be cleaned by means of a wire brush.

DRESSING THE PLUG. When the plug has been cleaned and before the gap is set, it is very important that the electrodes by dressed down to produce a flat, parallel surface on them. This removes oxidation. Also, a flat, parallel surface resists growth better, requiring less voltage to jump the plug gap. The plug is dressed by filing the electrodes with a thin point file or mail file, figure 72.

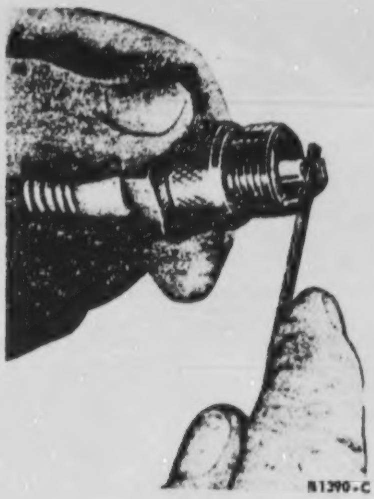


Figure 72. Filing Spark Plug Electrodes.

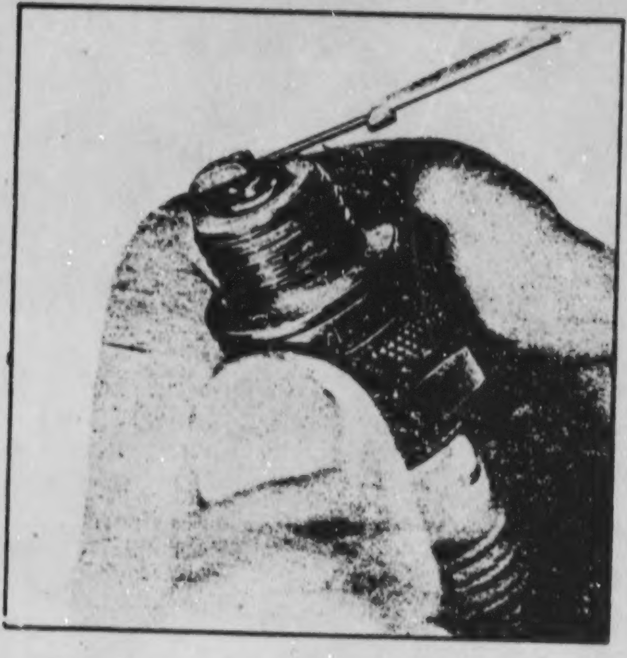


Figure 73. Setting Spark Plug Gap.

SETTING THE PLUG GAP, FIGURE 73. Setting the gap on the plug correctly is very important. When setting the gap, the center electrode should never be touched. Always bend the grounded electrode, figure 73, either toward or away from the center electrode. A wire feeler gage is used to measure the gap between the electrodes. Always refer to specifications for correct gap setting. A slight drag should be felt when the feeler gage passes between the electrodes.

TESTING THE SPARK PLUG. When the plug has been cleaned, inspected, and gapped, it is now ready for testing. However, if any defects were found when inspecting the plug there is no reason for testing it. In other words, the plug should be thoroughly checked visually. If no defects are found it should then be tested. The tester should be used accordingly.

> Note: Never assume that bench testing the plug simulates the compression pressures that the plug will be under during engine operation. Because of the variables, the bench test, while useful, cannot be measured by any specific PSI readings.

INSTALLING PLUGS. The gasket seats in the cylinder head must be clean to assure proper sealing and heat transmission. Whenever possible, new gaskets should be used. The spark plug should be seated onto the gasket by hand. Then tighten to the proper specifications. When the plugs have been installed correctly, connect the cable terminals.

Note: Failure to install plugs properly will cause them to operate at excessively high temperatures and result in reduced operating life under mild operation or complete destruction under severe operation where the intense heat cannot be dissipated rapidly enough.

Summary

Although the above information is very brief in nature, it should show that there are certain tests to be made on the ignition system to keep it in peak operating condition. The methods for making the tests will vary on different units and test equipment used. The student workbook will give step-by-step procedures on certain units. The commercial manuals or technical order should always be referred to when possible.

MAGNETO IGNITION SYSTEMS

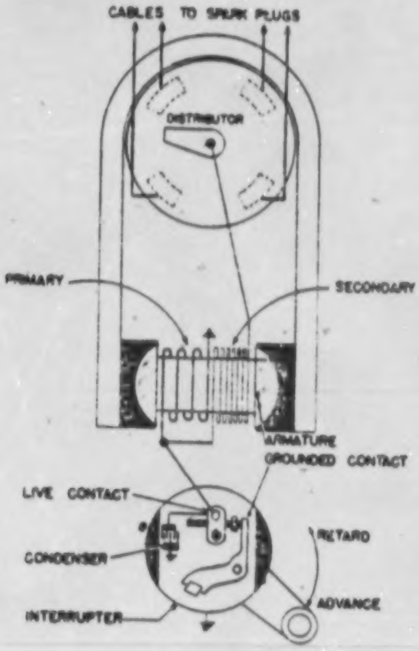


Figure 74. A High Tension Magneto.

The magneto mechanically generates electricity by electromagnetic induction. The purpose of the magneto is to take the place of the battery ignition system. The magneto is used when space is limited, weight is an important factor, and dependability is the first consideration. It is a compact combination of generator, ignition coil, and distributor, figure 74. The magneto requires no battery. It does have its disadvantages. Its principal one is that it turns so slowly during the cranking of the engine that a hot spark is not produced. Therefore, a supplementary high voltage source must be had. This can be a booster magneto or a high tension coil to which primary current comes from a battery. Also, some magnetos use an impulse coupler. This produces high armature speeds at cranking speeds to give a hot spark.

Operation of the Magneto

Three things are necessary to induce voltage--an electrical conductor, a magnetic field, and relative motion between the field and the conductor. In the magneto, a wire coil is the conductor, a permanent magnet provides the magnetic field, and the engine provides the mechanical energy for motion between the field and the conductor. The rest of the operation of this ignition system is very similar to the battery ignition system. As most engines require very high voltage at the spark gap in the cylinder, a device must be installed to raise the low voltage induced in the conductor (primary winding) to the required high voltage. This is done in the same way that it is in the battery ignition coil. To make this device work, a set of breaker points is found in the magneto. One end of the primary winding is connected to ground. The other is connected to the insulated breaker point. Lobes on a cam actuate the breaker points. The cam is mounted on either the armature or rotating magnet. A condensor is placed in parallel with the breaker points. When the breaker points are opened, the current then flowing in the primary circuit, due to self-induction, tends to arc across the points. This reduces the speed with which the circuit is broken and the magnetic field collapsed. This action is controlled by inserting the condenser. The device that directs the electrical impulses in proper order to the spark plugs is called the distributor rotor. It is usually driven through suitable gearing, at one-half crankshaft speed. The magneto cover is much larger than those used in the battery ignition distributors. It contains the contact spring and electrode which serve the same purpose as the rotor segment in the battery ignition distributor. In other words, the electrode connects the high tension leads to the spark plugs.

Types of Magnetos

Two types of magnetos are used--those in which the wound armature rotates, and those in which the permanent magnets rotate. The latter is classified as an indicator type magneto.

THE ARMATURE WOUND MAGNETO. This type of magneto is the same as an alternating current generator with permanent horseshoe type field magnets. Every time the armature rotates one-half turn, one impulse of electricity is generated.

THE INDUCTOR TYPE MAGNETO. This is a variation of the armature wound type. In this magneto the induction coil is held stationary around the armature shaft. Two soft iron induction pieces rotate on the armature shaft, thereby causing the magnetic field to rotate around the coil.

Low Tension and High Tension Type Magnetos

A low tension magneto is one which generates a low voltage electric current. The current is usually stepped up by an outside coil. The timing and distribution of the ignition spark are performed by breaker points and a distributor system located on one end of the magneto. The high tension magneto is similar in construction to the low tension magneto, except that it has the step-up coil built into the magneto itself. The voltage supplied directly to the spark plugs is about 6,000 volts.

Impulse Coupler

Since the average engine cannot be cranked fast enough by hand to start if it has an ordinary magneto, an impulse coupler is attached to the magneto. The impulse coupling must keep the magneto shaft from rotating for a short period during which the spring in the impulse coupler is being compressed. The spring is then suddenly released by a latch which is tripped during rotation. The energy stored in the compressed spring tension is enough to snap the magneto shaft over 1/2 turn to a turning speed equal to 500 to 600 rpm. This will produce the hot spark needed for starting the engine.

> Note: On most of today's vehicles using the magneto ignition system a battery energizes the cranking motor only. The engine does not have to be cranked by hand.

Booster Coil

Some units may use the booster coil to furnish the hot spark necessary for starting the engine during cranking. An external source of high tension current for starting is provided either by a booster magneto or by a high tension coil. The primary current is supplied by a battery. The coil method is most common. Current from the booster coil is conducted to the booster electrode of the magneto, This connects the booster coil with the magneto primary coil when the contacts open. This causes a current surge through the primary which produces a rapid change of magnetic field strength in the primary. This action induces in the secondary a high voltage surge strong enough to fire the plugs.

Magneto Switches

The magneto cannot be turned off by disconnecting it from some external source of energy as in the battery ignition. This is because the magneto is self-energizing. The method used to prevent the magneto from producing high voltage surges is to ground the primary circuit. Since one end of the primary circuit is already grounded, grounding the other end will turn it off. The grounding switch may be located according to the vehicle.

Maintenance of the Magneto

When magneto failure occurs the two most frequent causes are burning of the contact points or condenser failure. The magneto should be oiled periodically according to the manufacturer's instructions. It is very important not to overoil the bearings. This can also be a source of magneto failure.

QUESTIONS

1. The ignition system consists of a primary and secondary circuit. Why does the secondary circuit wiring have the heavier insulation?

2. What is the primary purpose of the ignition condenser in the ignition system?

3. When the ignition points are closed, what takes place within the coil?

4. What are the units which make up the primary circuit of the battery ignition system?

5. What are the units which make up the secondary circuit of the battery ignition system?

6. Why is the magneto used on some applications?

7. What induces the high voltage into the secondary winding of the ignition coil?

8. What device is used with the 12-volt ignition coil to control primary current flow?

9. What is the purpose of the centrifugal advance mechanism?

10. What operates the centrifugal advance?

11. Why is the vacuum mechanism installed along with the centrifugal advance mechanism?

12. When is the vacuum advance effective?

13. What is the preferred method of checking the contact points?

14. How is the contact point pressure increased or decreased?

15. Why should the spark plug be checked for reversed polarity?

16. What kind of voltage should the spark plug terminal always have?

17. What is the meaning of the term "heat range" as applied to spark plugs?

18. What is the difference between the power tip spark plug and the standard spark plug?

19. What is the reach of the spark plug?

20. How is the thread size determined on a spark plug?

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-SG-303

CRANKING MOTORS AND STARTING SYSTEMS

OBJECTIVES

Upon completion of this study guide and your classroom instruction, you will be able to relate the operating principles and maintenance procedures of starting motors, starter switches, drives and circuits; use test equipment for testing starters and starter circuits; remove, inspect, repair or replace, install and adjust starting motors and starting system units and observe applicable safety precautions.

INTRODUCTION

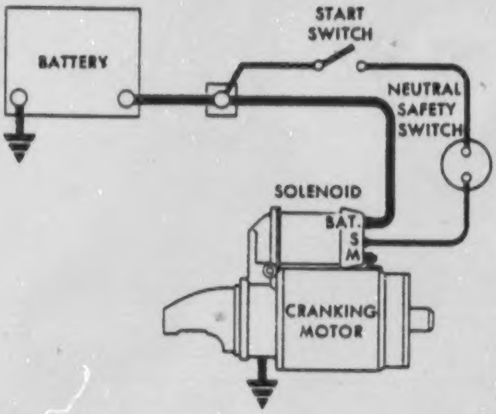


Figure 75. The Starting Circuit.

The starting system gives power for cranking the internal combustion engine. This power is provided by the battery through the use of the starting motor, or starter. The starting system, figure 75, consists of the battery, starter switch, and the starting motor. At one time cranking of the engine was accomplished by hand with a simple crank. Now the electric starter is used on all automobiles and most trucks, tractors, and construction equipment using the internal combustion engine. The importance of maintaining the starter system in good working order cannot be overemphasized since a vehicle that will not start is completely useless.

INFORMATION

STARTING MOTORS

The electric motor is device that converts electrical energy into mechanical action. It makes use of current flow from the battery to produce mechanical movement. The starting motor is a special overload, direct current motor that can give a high horsepower for short periods of time only. If it is operated under a load for longer than 30 seconds it may overheat and burn out. It is called a direct current motor because current flows through it in only one direction. Remember that direct current (DC) always flows in one direction.

Principles of Electric Motors

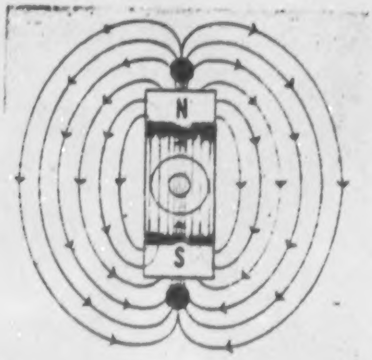


Figure 76.
A Magnetic Field Is
Strongest at the Poles.

Remember from a previous lesson that there is a magnetic field between the two poles of a magnet. This magnetic field consists of invisible lines of force moving from the north pole to the south pole of the magnet. Also remember that a current carrying conductor has a magnetic field around it. Figure 76 shows what happens when we place this current-carrying conductor in the magnetic field produced by two magnets. Notice how many more lines of force there are on the left side of the conductor, and how few on the right side. There is a strong field on one side and a weak field on the other. These lines of force are like rubber bands. When they are bent, they try to straighten out. As they try to straighten out, the lines of force push on the conductor, causing the conductor to move in the direction shown.

Instead of a straight wire, a loop of wire will now be placed in the magnetic field provided by the two magnets. An electric current is passed through the loop in the direction shown in figure 77. The loop will now rotate in a clockwise direction. Figure 78 shows why. At point A, the lines of force are squeezed together below the wire loop. The lines of force tend to push this side of the loop up. At point B, the lines of force are squeezed together above the loop. This tends to push the right side of the loop down. When these two forces are combined, the loop will rotate in the direction shown by the large arrows. This is basically how the starting motor rotates. Anytime a current-carrying conductor is placed in a magnetic field, the result is movement, or motion.

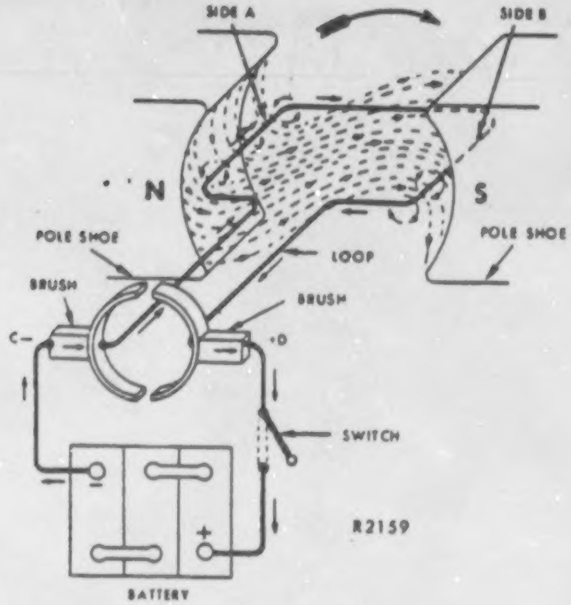


Figure 77. Simple Single-Loop Direct Current Motor.

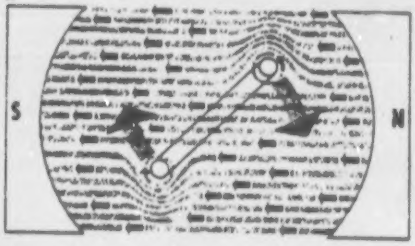


Figure 78. Magnetic Field Pattern of Starting Motor.

Construction of the Starting Motor

The construction of the starting motor is similar to the single loop motor shown in figure 77. The starting motor used on automotive vehicles consists of the pole pieces and field windings, the armature and commutator assembly, brushes, and frame. Figure 79 shows a cutaway view of a typical starting motor.

THE POLE PIECES. The magnetic field in the starting motor is supplied by two or more pole pieces with loops of wire around them. The poles of the magnets are called pole shoes. The wire wound around these pole shoes are called field windings. When current is flowing through the field windings, the pole shoes become strong electromagnets.

THE ARMATURE AND COMMUTATOR ASSEMBLY. In the starting motor there is more than one loop of wire. These loops of wire are combined to form the armature. When a current is passed through the starter, it goes through one loop of-the armature.

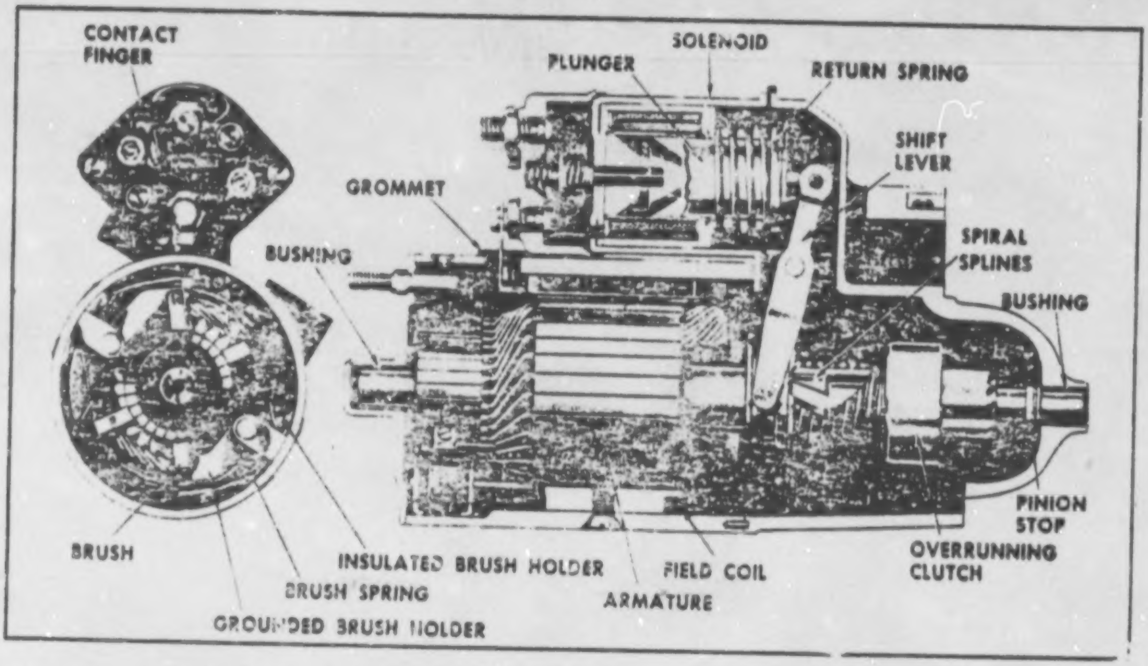

CONTACT FINGER
SOLENOID
PLUNGER
RETURN SPRING
SHIFT LEVER
GROMMET
SPIRAL SPLINES
BUSHING
BUSHING
PINION STOP
OVERRUNNING CLUTCH
BRUSH
INSULATED BRUSH HOLDER
FIELD COIL
BRUSH SPRING
ARMATURE
GROUNDED BRUSH HOLDER

Figure 79. Starting Motor Cross Section (Typical).

This causes the armature to rotate. As soon as the armature rotates a little, current shifts to another loop. The armature then turns a little more. This is what causes the armature to turn. Each end of the loops of wire is connected to a split ring. For each loop of wire there is a pair of these split rings. These split rings are called commutator segments or commutator bars. Putting these segments together make up the commutator.

THE BRUSHES. Electrical connection is made with the commutator through the use of brushes. Brushes are blocks of copper which ride on the commutator. When the starting motor is in operation, current flows from the battery to the starting motor terminal. Current then flows through the field windings. From there, current goes through one brush into the commutator. This brush is called the insulated brush. The insulated brush does not touch ground. Current then flows through the armature windings in the motor. After passing through the armature, current is picked up by another brush. This brush is called the ground brush. The ground brush is attached directly to the frame of the starter. Current then flows back to the battery.

MOTOR FRAME. The starter housing or frame provides a place onto which the pole shoes and field windings can be assembled. The frame also provides a low resistance path for the magnetic flux produced by the field coil windings. Remember that magnetic lines of force will travel through iron easier than air and that they must form a complete circuit.

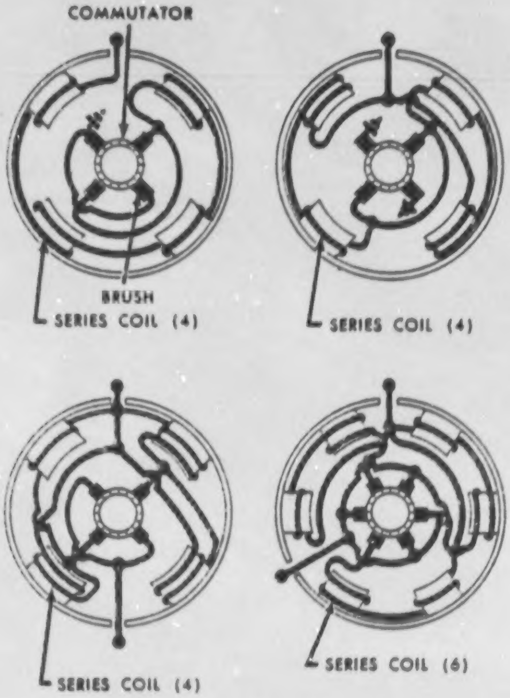

COMMUTATOR
BRUSH
SERIES COIL (4)
SERIES COIL (4)
SERIES COIL (4)
SERIES COIL (6)

Figure 80. Different Field Circuit Wiring Arrangements.

FIELD WIRING. An inspection of the wiring diagrams shown in figure 80 shows various combinations of series, series-parallel, and parallel connections. The one selected for any particular application is dependent on many factors, such as engine speed and torque requirements, cable size, battery capacity, and the current carrying capacity of motor brushes and switches. There are two types of field coils used in cranking -- series and shunt.

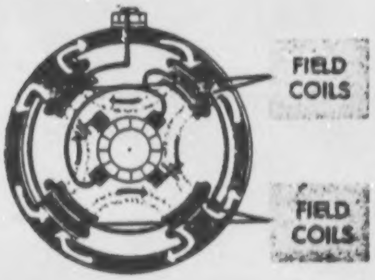

FIELD COILS
FIELD COILS

Figure 81. Straight Series Winding.

Straight Series Winding. The field windings are connected in series with the brushes and armature windings, so the current that flows through the field windings also flows through the armature windings, figure 81. Series coils contain several heavy copper ribbon conductors. This permits an extremely large current to flow, so that the motor develops high torque, or turning effort.

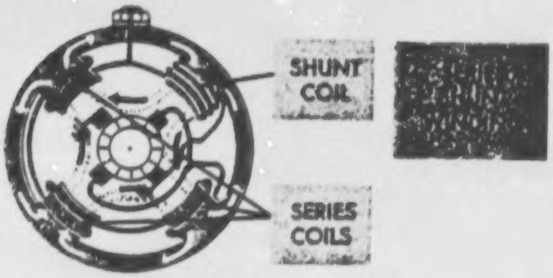


Figure 82. Series Shunt Winding.

Series-Shunt Winding. Current going through a starter shunt coil bypasses the armature and flows directly back to the battery. The shunt coil can be identified by its direct connection to ground, figure 82. The shunt coil contains many, many turns of smaller wire. The shunt coil is designed to keep the magnetic field of the starter strong. By keeping the field strong, the shunt coil prevents the motor from overspeeding. Many times the starting motor will try to obtain a maximum speed that is so high that the motor will tend to tear itself apart. The maximum speed of the starter is controlled by the shunt coil. The remainder of the field coils, the series coils, are the same as that described in the previous paragraph.

Variations in Starting Motor Constructions

The above description of the construction of the starting motor has been that of the typical starter. There are two variations which you should be aware of however. These are the reduction gear starting motor and the moveable pole shoe starting motor.

REDUCTION GEARS. This type of starting motor is usually found only in Chrysler products. Figure 83 shows a reduction gear motor. The purpose of the reduction gears is to produce more torque or turning power at the drive pinion. These gears also cause the pinion to turn slower than the armature, making it necessary to have a faster turning armature for the engine to be turned over at the speed required.

MOVEABLE POLE SHOE STARTER. This type of device is now found on Ford Motorcraft (formerly Auto-Lite) starters. The Ford starter is shown in figure 84. When the ignition switch is turned to the start position, current flows through one field coil and a set of contact points to ground. The magnetic field given off the field coil pulls the moveable pole shoe down to its seat. When the pole is pulled down, the lever moves the drive assembly into mesh with the engine flywheel. When the moveable pole is seated, it opens the contact points and functions as a normal field coil. With the points open,

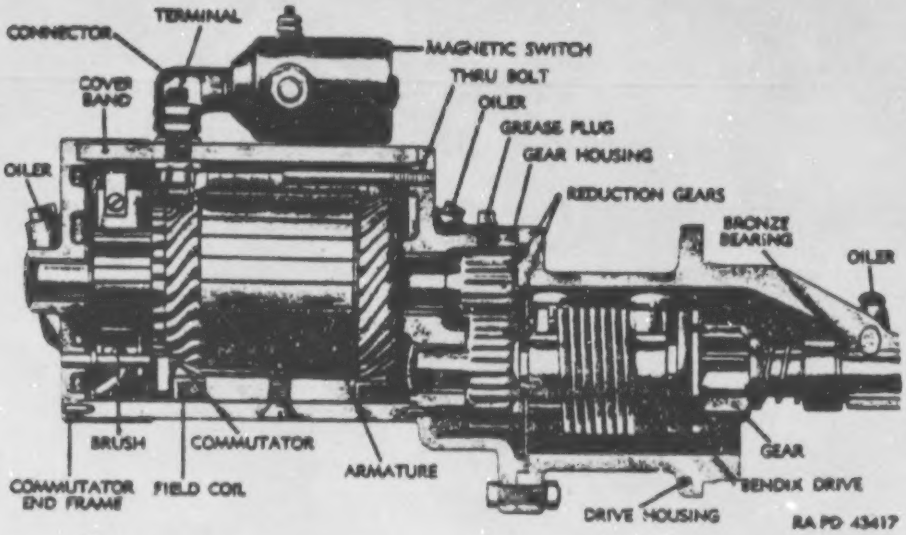

TERMINAL
CONNECTOR
MAGNETIC SWITCH
THRU BOLT
COVER BAND
OILER
GREASE PLUG
GEAR HOUSING
OILER
REDUCTION GEARS
BRONZE BEARING
OILER
BRUSH
COMMUTATOR
ARMATURE
GEAR
COMMUTATOR END FRAME
FIELD COIL
BENDIX DRIVE
DRIVE HOUSING
RA PD 43417

Figure 83. Chrysler Reduction Gear Starter.

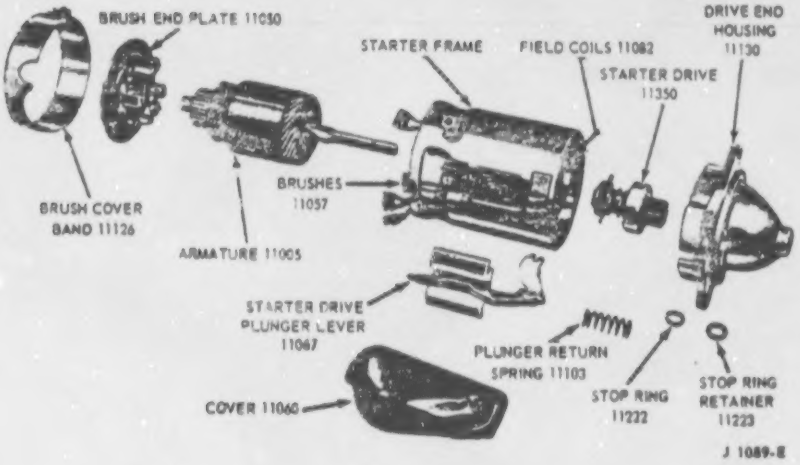

BRUSH END PLATE 11030
DRIVE END HOUSING 11130
STARTER FRAME
FIELD COILS 11082
STARTER DRIVE 11350
BRUSHES 11057
BRUSH COVER BAND 11126
ARMATURE 11005
STARTER DRIVE PLUNGER LEVER 11067
PLUNGER RETURN SPRING 11103
COVER 11060
STOP RING 11222
STOP RING RETAINER 11223
J 1089-E

Figure 84. Ford Starter Disassembled.

current flows through all field coils energizing the starter. At the same time, current also flows to another coil which holds the moveable pole down. When the ignition switch is released from the START position, a return spring pushes the moveable pole back to its original position.

Starter Drives

The motor drive mechanism is assembled onto the armature shaft, and is the part through which power is transmitted from the armature to the engine when cranking the vehicle. There are a number of different types of starter drive units. These are covered in the sections that follow.

All drives, regardless of type, contain a pinion which is made to move along the shaft and engage the ring gear for cranking purposes. A gear reduction is provided between the pinion and ring gear. With the gear reduction feature, the motor operates to crank the engine at speeds sufficient for starting purposes. After the engine has started, it is possible that the ring gear would drive the armature at speeds which would cause the windings to be thrown from their slots. Therefore, all drive mechanisms are designed to disengage the pinion from the ring gear or to provide an overrun feature when the engine begins to drive the pinion faster than the armature. This feature protects the armature from being driven to damaging speeds.

Bendix Drive

Although there are a variety of different types of Bendix drives which may differ considerably in appearance, each drive operates on the principle of inertia to cause the pinion to engage with the engine ring gear. Inertia is that property of matter by virtue of which any physical body remains in its state of rest or of uniform motion until acted upon by some external force.

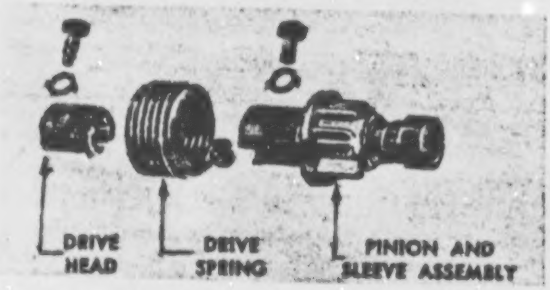


Figure 85.
Simple Bendix Starter Drive.

CONSTRUCTION OF THE BENDIX DRIVE. Figure 85 shows a disassembled view of the Bendix drive. The drive pinion is normally unbalanced on one side, and has screw threads or splines cut on its inner bore. These screw threads match the screw threads cut on the outer surface of the Bendix sleeve. The pinion and sleeve assembly fits loosely over the armature shaft. It is connected through the drive spring to the drive head. The drive head is keyed to the shaft. The pinion and sleeve assembly is free to turn on the armature shaft to the extent permitted by the flexing of the drive spring.

ENGAGEMENT OF PINION TO FLYWHEEL. When the starting switch is closed and the motor windings are energized by the battery, the armature starts to rotate. This rotation is transmitted through the drive head and drive spring to the sleeve, and these parts increase in speed with the armature. The pinion, however, being unbalanced and having a loose fit on the sleeve, does not increase in speed with the armature due to its inertia. The result is that the spiral splined sleeve rotates within the pinion, and the pinion moves endwise, or "walks out", along the shaft to engage the ring gear. When the pinion reaches its stop on the sleeve, cranking takes place, with the initial shock of engagement being taken up by the spring.

DISENGAGEMENT OF BENDIX FROM THE FLYWHEEL. When the engine begins to operate, the pinion is driven by the ring gear at a higher speed than the armature. This causes the pinion to rotate in the same direction as the sleeve but at a higher speed. The pinion is then driven back out of mesh with the ring gear teeth. For as long as the operator keeps the motor energized with the engine running, the motor free speeds. The motor start switch, therefore, should be released immediately after the engine has started.

> Note: Some Bendix drives contain a spring-loaded detent pin. This feature prevents unwanted disengagement of the pinion during a false start.

Overrunning Clutch

Another type of starter drive is the overrunning clutch. This drive does the same thing as the Bendix; it connects and disconnects the starter to and from the flywheel ring gear.

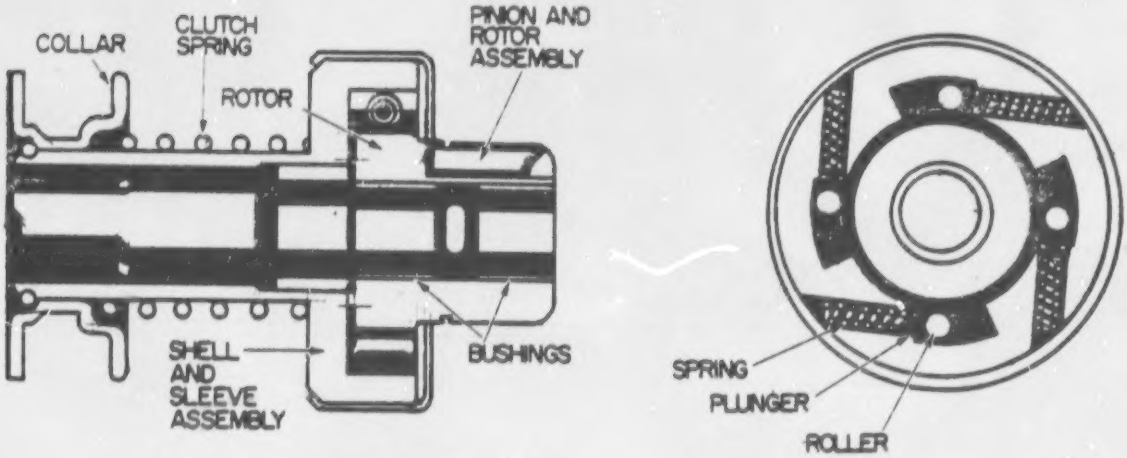


Figure 86. Typical Overrunning Clutch Construction.

CONSTRUCTION OF THE OVERRUNNING CLUTCH. The overrunning clutch pinion is moved into and out of mesh with the ring gear by a shift lever which is operated either manually or by a solenoid. The overrunning clutch drive, figure 86, has a shell and sleeve assembly which is splined internally to match either straight or spiral splines on the armature shaft. The pinion is located inside the shell along with spring-loaded rollers that are wedged inside the shell. A collar and spring located over the sleeve are the other major components.

ENGAGEMENT OF OVERRUNNING CLUTCH. When the shift lever is operated, the shift lever moves the collar endwise along the shaft, and the spring pushes the pinion into mesh with the ring gear. If a tooth abutment should occur, the spring compresses with lever movement until the switch is closed, at which time the armature starts to rotate and the tooth abutment is cleared. The compressed spring then pushes the pinion into mesh. Cranking begins with torque being transmitted from the shell to the pinion by the rolls which are wedged tightly between the pinion and taper cut into the shell.

DISENGAGEMENT OF OVERRUNNING CLUTCH. When the engine starts, the ring gear drives the pinion faster than the armature rotation. The rolls are moved away from the taper allowing the pinion to overrun the shell. The start switch should be opened immediately when the engine starts to avoid prolonged overrun. When the shift lever moves back by return spring or manual action, the pinion is moved out of mesh and the cranking cycle is completed.

Summary

Whether the Bendix or overrunning clutch starter drive is used, remember that their purposes are the same. First, they connect the starting motor to the engine flywheel and transfer the torque of the motor to the engine for cranking. Second, the starter drive units disconnect the starter from the flywheel after the engine has started. Remember to release the motor start switch as soon as the engine has started to prevent serious damage to the drive unit.

STARTING MOTOR CONTROLS

During the cranking of a vehicle a very high current is used. The starting motor may draw several hundred amperes from the battery during this period. Switches able to carry this high current without over-heating or damage to them must be used. The switches will assume different forms when used on different units. The two main controls used on today's vehicles are the magnetic switch and the solenoid.

The Magnetic Switch

The magnetic switch is used on starting motors which have the Bendix drive. The magnetic switch utilizes the principle that a flow of current in a winding of wire creates a magnetic field. A magnetic switch, figure 87, consists of a winding of wire mounted around a hollow cylinder. An iron plunger is placed inside this cylinder. A contact disc is assembled into the plunger. When the ignition switch is turned to the START position, the winding is energized. The movement of the

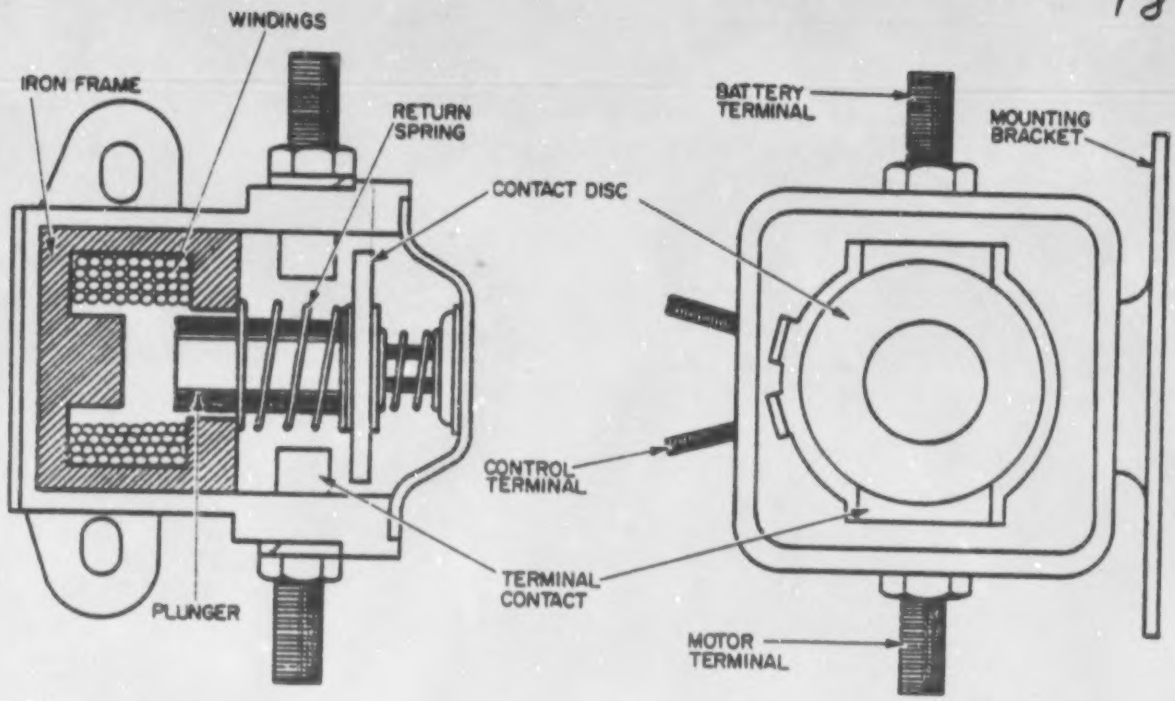


Figure 87. Magnetic Switch.

plunger causes the contact disc to be held tightly against the two main switch terminals. The circuit is now closed between the starting motor and the battery and cranking takes place. When the ignition switch is released, the winding is deenergized. A return spring causes the plunger to return to its original position. The circuit between the battery and starting motor is now open. The magnetic switch, therefore, is a mechanical switch that is operated electromagnetically. Remember that magnetic switches are manufactured in a wide variety of designs, but each operates on the principle just outlined. The only purpose of a magnetic switch is to connect the battery to the starting motor. Different magnetic switch circuits used to connect the battery to the starting motor are shown in figure 88.

Solenoids

When the overrunning clutch drive is used on the starting motor, the magnetic switch is given an additional job to do; then it is called a solenoid, figure 89. The solenoid switch consists basically of two windings mounted around a hollow cylinder containing a moveable plunger. A shift lever is connected to the plunger and a contact disc is assembled in line with the plunger. When the windings are energized, the plunger pulls the shift lever. This moves the overrunning clutch into mesh with the ring gear. The contact disc is pushed into contact with the solenoid battery and motor terminals. Cranking of the engine now takes place. The two windings in the solenoid are the pull-in and the hold-in windings. The pull-in winding

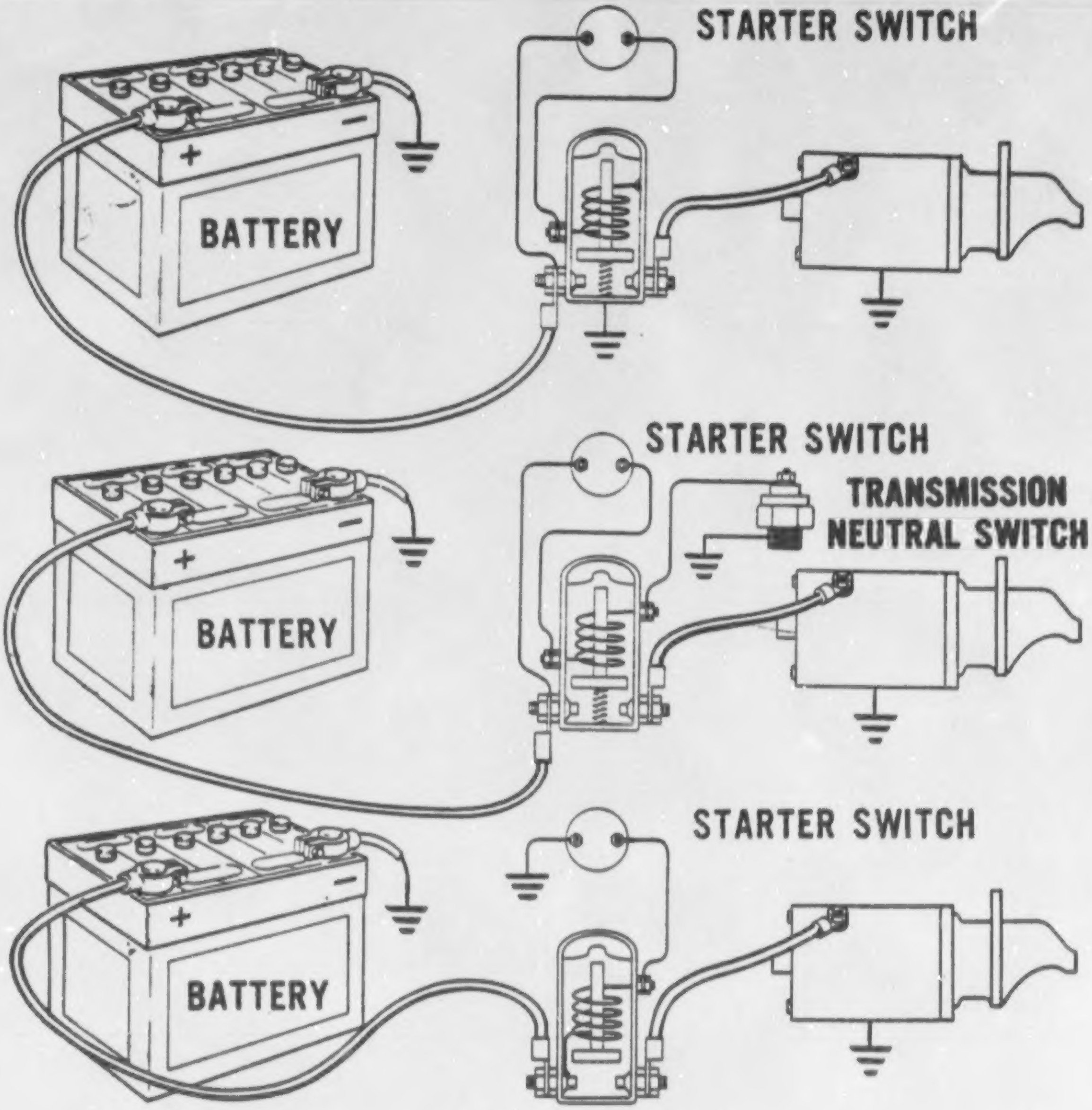

STARTER SWITCH
+
−
BATTERY
STARTER SWITCH
TRANSMISSION NEUTRAL SWITCH
+
−
BATTERY
STARTER SWITCH
+
BATTERY

Figure 88. Magnetic Switch Circuits.

has a few turns of heavy wire, while the hold-in winding has many turns of fine wire. When the ignition key is turned to the "START' position, current flows from the battery through both these windings. The current returns to the battery from the hold-in winding directly through ground. The current passing through the pull-in winding must flow through the cranking motor before returning to the battery. This hook-up causes the pull in winding to be shorted out when the plunger pushes

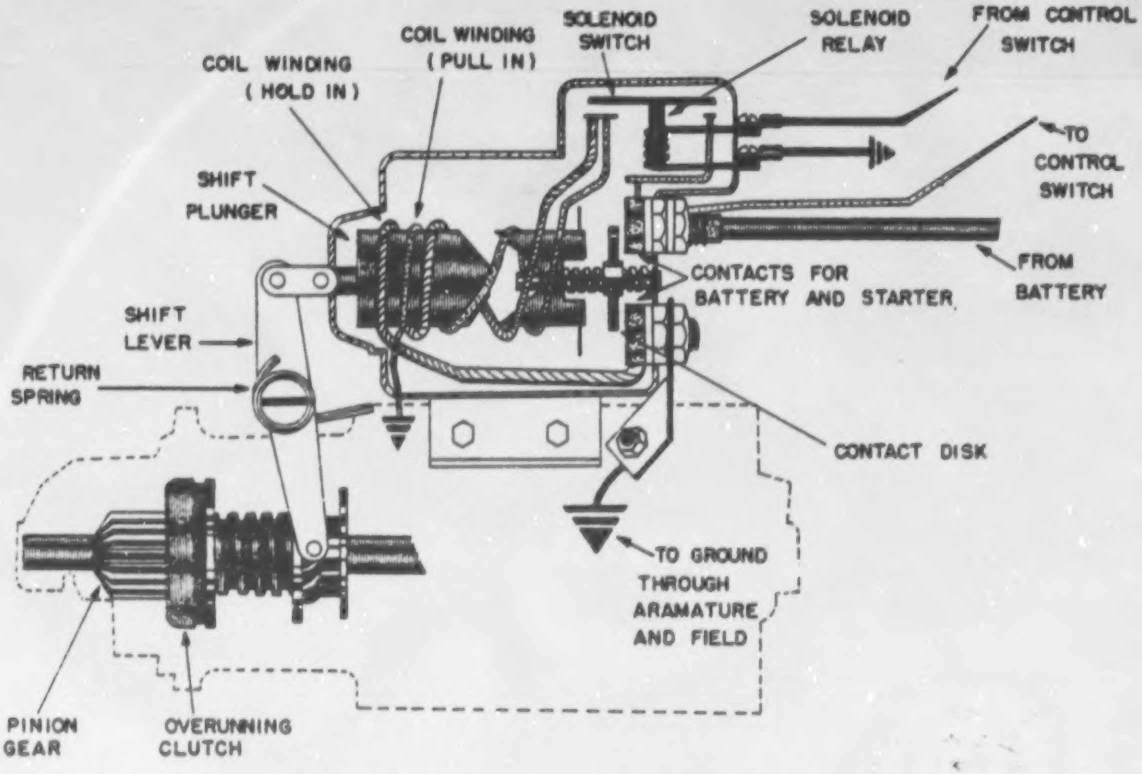

SOLENOID SWITCH
COIL WINDING (PULL IN)
COIL WINDING (HOLD IN)
SOLENOID RELAY
FROM CONTROL SWITCH
TO CONTROL SWITCH
SHIFT PLUNGER
FROM BATTERY
CONTACTS FOR BATTERY AND STARTER
SHIFT LEVER
RETURN SPRING
CONTACT DISK
TO GROUND THROUGH ARAMATURE AND FIELD
PINION GEAR
OVERRUNNING CLUTCH

Figure 89. Starter With Solenoid Switch and Overrunning Clutch.

the contact disc in. Shorting out the pull-in winding lessens the drain on the battery and leaves more energy for cranking. More magnetism is needed to pull the plunger in, so both windings work together to accomplish this. Once the plunger is in however, less magnetism is needed to hold it in.

MAINTENANCE OF STARTER COMPONENTS

Starting Motor

Normally, the disassembly of starting motors should proceed only as far as necessary to make the repair or replacement of parts. Certain checks are common on most cranking motors. These tests should be made on disassembled starters before making starter tests using specialized test equipment.

BRUSHES. They should not be worn down more than one-half their original length. If the brushes are worn more than this amount, they should be replaced. Check this condition by comparing the starter brush to a new brush of the correct size for the starter.

BRUSH HOLDERS. The spring tension of the brush holders for freeness of operation.

ARMATURE. Visually check the armature windings for broken or burned insulation and unsoldered connections.

COMMUTATOR. The commutator should be checked for glazed or dirty condition. If dirty, it can be cleaned using No. 00 or 000 sandpaper. Never use emery cloth to clean the commutator. If the commutator is found to be rough, out of round (.005" or more), has high mica, or is extremely dirty, it will require turning down in a lathe. The mica insulation must then be undercut and the slots cleaned out to remove any trace of dirt or copper dust.

BUSHINGS. There should be very little play between the armature shaft and the bushings. Inspect the bushings for excessive scouring and wear. Check the armature for signs of rubbing on the pole shoes. If there is too much play or if the armature has been rubbing on the pole shoes, replace the bushings.

Starter Drives

BENDIX DRIVE. Maintenance of the Bendix drive consists of the following:

1. Visually inspect for damaged pinion gears.

2. Check for free screw action between the pinion gear and sleeve.

3. Check the spring. If it is bent, broken, or the eyes are spread open, the spring must be replaced.

4. Lubricate the drive unit with light engine oil. Never use grease.

OVERRUNNING CLUTCH. Maintenance on this type of drive consists of the following:

1. Visually check for damaged pinion gears.

2. Check for free movement of the collar on the shell and sleeve assembly.

3. Check the condition of the pinion assembly by holding the shell sleeve assembly and rotating the drive gear both ways. It should rotate freely in one direction and lock in the other.

4. Never immerse or soak the overrunning clutch in solvent. The grease will be washed out of the clutch assembly and there is no way to regrease it. Clean using a damp cloth.

5. Lubricate the sleeve with light engine oil.

TESTING THE STARTING MOTOR

For a starting motor to produce its full power with the least amount of amperage draw, all of the electrical circuits must be in good condition. Each unit of the starting motor should be tested separately with the proper test equipment. This eliminates the possibility of placing a defective unit back into the starting motor upon reassembly. A brief description of each test follows.

Armature Testing

The armature should be tested for grounds, shorts and open circuits whenever the starting motor is overhauled. The following procedures are typical but be sure to check manufacturer's manual for the correct procedure for the equipment being used.

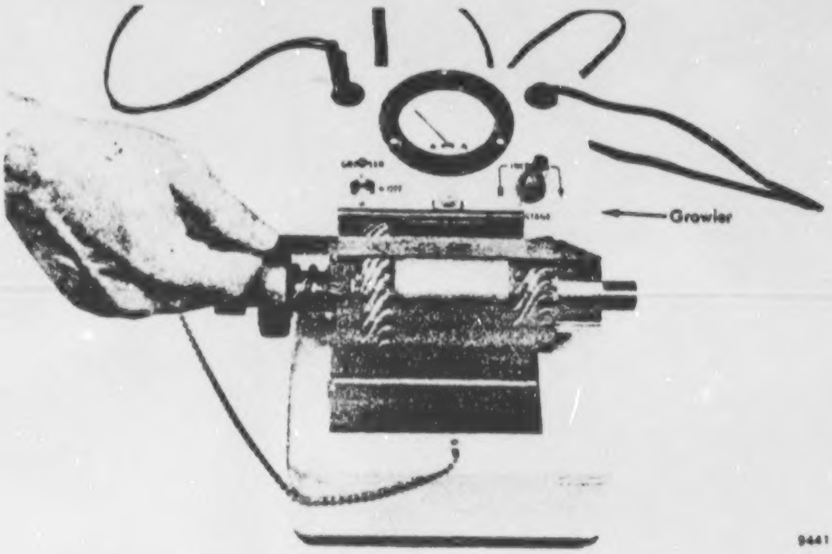


Figure 90. Armature Short Test.

SHORT CIRCUITS. The armature is tested for short circuits on an armature tester, commonly called a "growler." The armature is placed in the growler jaws and slowly revolved while holding a steel blade above the armature core, figure 90. If there is a short circuit in one of the cores, the steel blade will vibrate against that core when held above it.

> Caution: Never operate the growler in the growler test position without an armature in the jaws.

UNWANTED GROUNDS. This test is made with the test lamp on the growler. One test point is placed on the armature shaft and the other is placed on the commutator, figure 91. If the lamp lights, the armature is grounded.

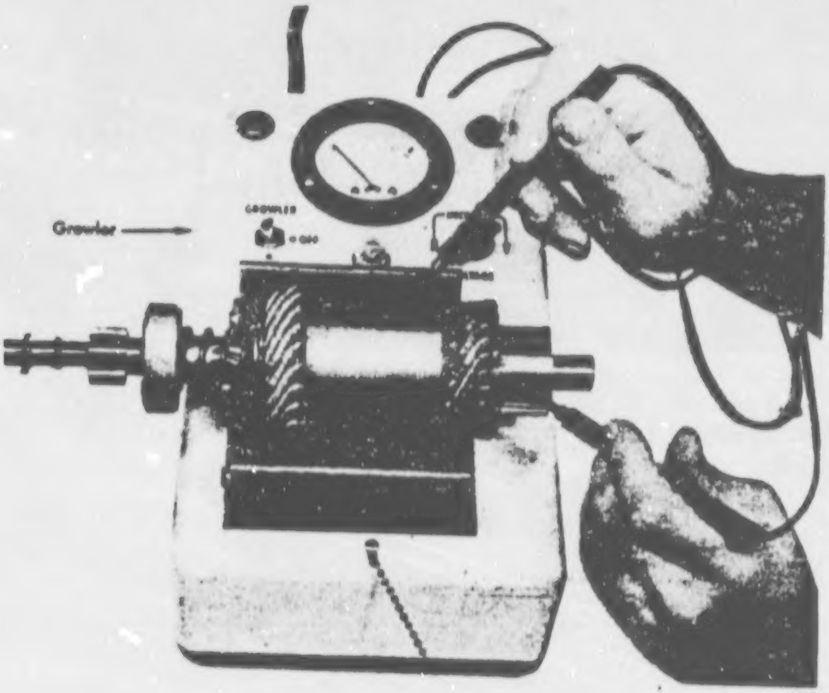


Figure 91. Armature Ground Test.

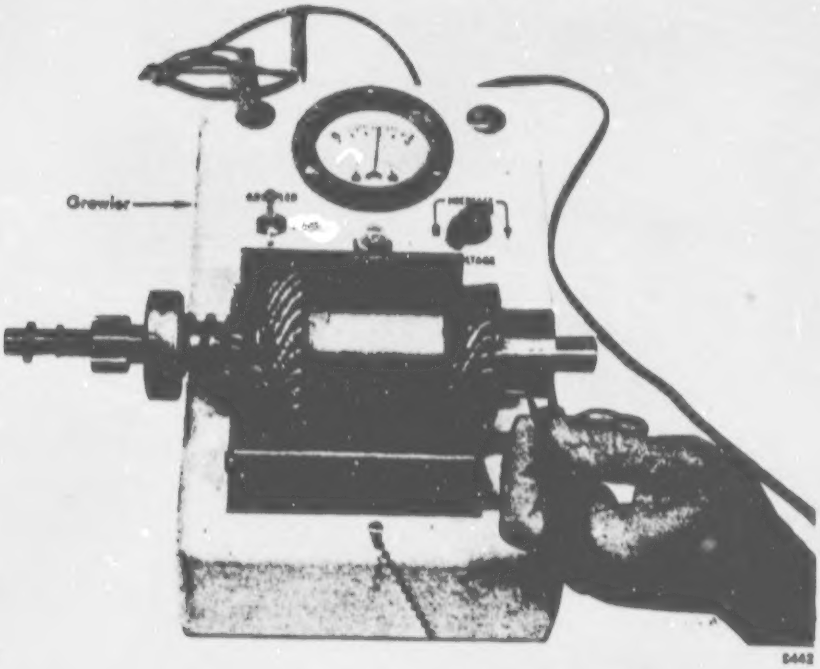


Figure 92. Armature Open Test.

OPEN CIRCUITS. If the armature has an open circuit, it may show visually at the commutator. The commutator bars will be badly burned. The ammeter on the growler is also used. Place the contact fingers of the growler test meter cable across adjacent commutator bars, figure 92.

Test each commutator bar with the next until all bars have been checked. A low reading indicates an open circuit in the particular pair of segments.

Field Coil Testing

The starter field coils are tested for open circuits and unwanted grounds. Again, the following procedures are typical, but be sure to check the manufacturer's specific procedures.

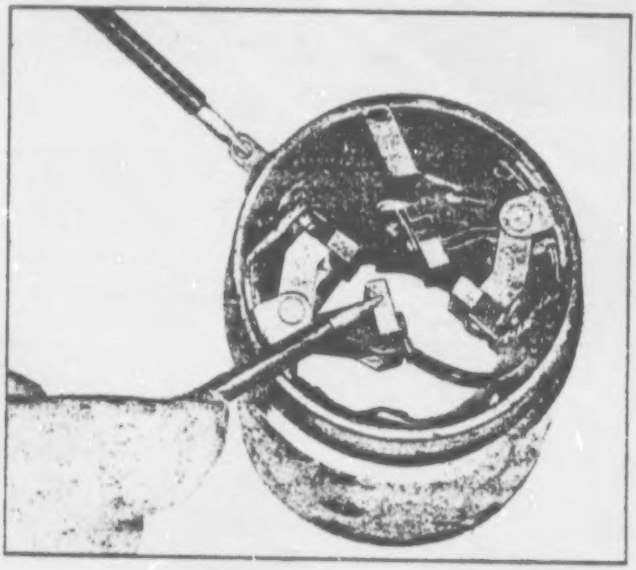


Figure 93. Field Coil Open Circuit Test.

FIELD OPEN CIRCUIT. This test will determine if the field windings are broken internally. The test lamp on the growler is used for this test. Place the leads of the test lamp at the two ends of the field circuit, figure 93. If the lamp does not light, the field windings are open and must be replaced.

FIELD GROUNDED CIRCUIT. This test will determine if the field winding insulation has failed permitting a conductor to touch the frame. The test lamp is also used on this test. One point is placed on the motor terminal of the starter and the other lead on the frame, figure 94. If the test light glows, the field windings are grounded and must be replaced.

ON VEHICLE STARTING SYSTEM TESTS

Trouble may develop in the starting motor system on the vehicle. There are several checks that can be made to determine whether the trouble lies in the battery, the starting motor, in the wiring circuit, or elsewhere. There are many conditions besides defects in the starter motor which can cause poor cranking performance.

Quick Testing of Starting System

To make a quick check of the starter motor system, with the battery fully charged, turn on the headlights of the vehicle. The lights should

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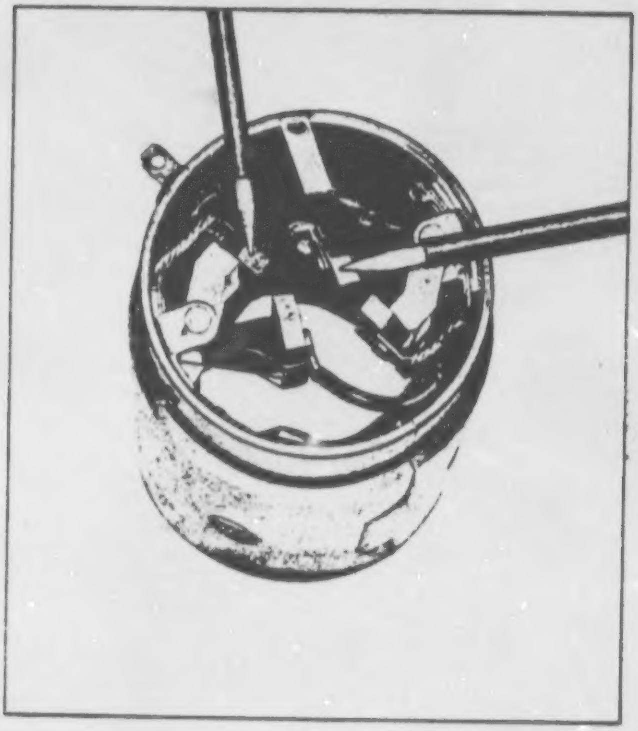

Figure 94. Field Coil Ground Test.

burn with normal brightness. Next, crank the engine and observe the brilliance of the headlights and the cranking speed.

LIGHTS GO OUT. If the lights go out as the starting motor is cranked, it indicates that there is a poor connection between the battery and the cranking motor.

LIGHTS DIM CONSIDERABLY. This may occur when the starting motor operates slowly or not at all. The trouble may be some mechanical condition in the engine or the starting motor itself.

LIGHTS STAY BRIGHT BUT NO CRANKING ACTION. This condition indicates an open circuit at some point. It could be either in the starting motor, starting motor switch, or in the control circuit.

Insulated Circuit Resistance Test

The purpose of this test is to measure the resistance of the cables and switches from the battery to the starting motor. In this test, the engine is cranked with a voltmeter connected across the circuit. Excessive voltage drop indicates resistance which may result in starting difficulties.

Ground Circuit Resistance Test

The purpose of this test is to measure the voltage drop in the starting motor ground circuit system. This test is performed similar to the insulated circuit test.

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Amperage Draw Test

Sometimes the starter will turn the engine slowly because the starter is drawing too little current. This condition may be due to poor connections within the starter, poor brush contact, etc. When it is found that the amperage draw is higher than specified by the vehicle manufacturer, various things within the starter could cause the trouble, such as the armature rubbing the field shoes or a grounded starting motor field coil. If the amperage draw is not within specifications, the motor must be removed from the vehicle and bench tested.

> Note: The importance of maintaining the battery in a fully charged and otherwise good condition for cranking motor performance cannot be over-emphasized. If poor cranking is encountered, the condition of the battery should be checked thoroughly. Of equal importance for maximum cranking output is the maintenance of all wiring in a clean and tight condition. Clean, tight connections become all important to avoid excessive voltage drop in the starter circuits.

QUESTIONS

1. The rotation of a starting motor is due to what?

2. What is a starting motor?

3. What is the purpose of a starting motor?

4. Magnetically, what two parts does the starting motor consist of?

5. What is the purpose of the magnetic field windings in the starting motor?

6. What are the two most common types of drive mechanisms in use today?

7. What is the purpose of these drive mechanisms?

8. What are the two types of controls used when the overrunning clutch type drive is used on the starting motor?

9. What may occur if the starting motor switch is kept engaged too long after the engine begins to operate?

10. Briefly explain the operation of the overrunning clutch mechanism.

11. What type of control is used with the starting motor using the Bendix drive mechanism?

12. Briefly explain the operation of a Bendix drive.

13. What method is used for cleaning a dirty or glazed commutator?

14. Why shouldn't a starting motor be operated for more than 30 seconds at a time without pausing?

15. Why is it so important that all starting system cables be of adequate size?

16. What will dirty cable connections cause?

DC CHARGING SYSTEM

OBJECTIVE

After completing this study guide and your classroom instruction, you will be able to explain the principles of operation, function and relationship of DC charging system components; repair and service DC charging system components; and be able to use visual, auditory, operational means and test equipment to check, adjust and isolate malfunctions in the DC charging system.

INTRODUCTION

The charging system is sometimes called the "power system" and sometimes the "battery generator system". The efficiency of the entire electrical system depends upon its ability to function normally. Any weakness of the charging system will show in the performance of the cranking, ignition, lighting, warning and accessory systems. Therefore, it is very important that the charging system is thoroughly understood. The charging system consists of three basic units--the battery, generator, and generator regulator. Broadly speaking, the battery and generator work together. These two units keep a supply of power available as required by all the electrically operated units of the vehicle. The regulator is a control device designed to prevent damage to the generator, battery, and voltage sensitive parts of the electrical system.

INFORMATION

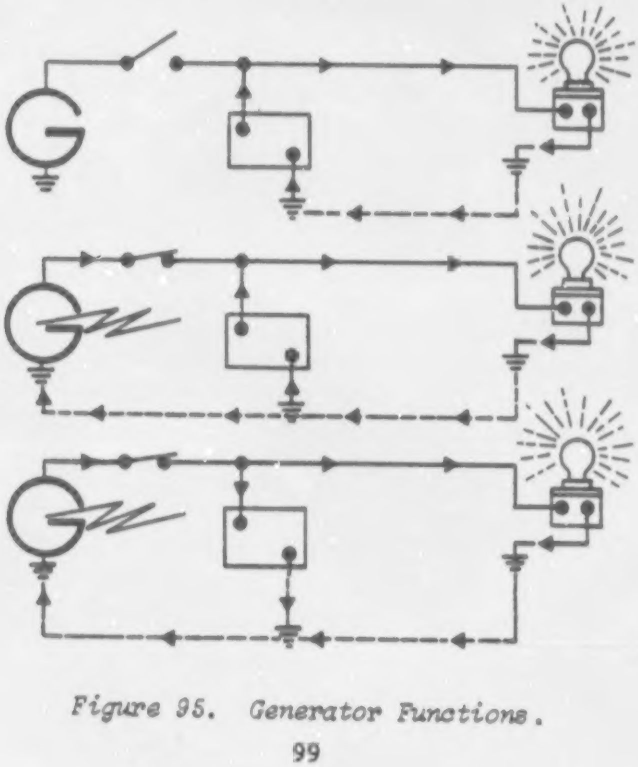

Figure 95. Generator Functions.

The DC charging system uses a generator to supply power to the vehicle electrical system. The purpose of the generator charging system is two-fold. First, it must charge the battery. Second, it must supply power to the vehicle's electrical system. Figure 95 shows how the generator and the battery work together to supply electrical power to the vehicle electrical system. When the generator is at rest or is operating at an extremely low speed, such as at engine idle, the electrical energy for ignition, lights and accessories is supplied by the battery alone. When the generator is operating at medium speed, energy is supplied to the electrical system by both the generator and the battery. At high speeds, such as driving on an interstate highway, the generator alone supplies electrical energy to recharge the battery and to power the electrical system.

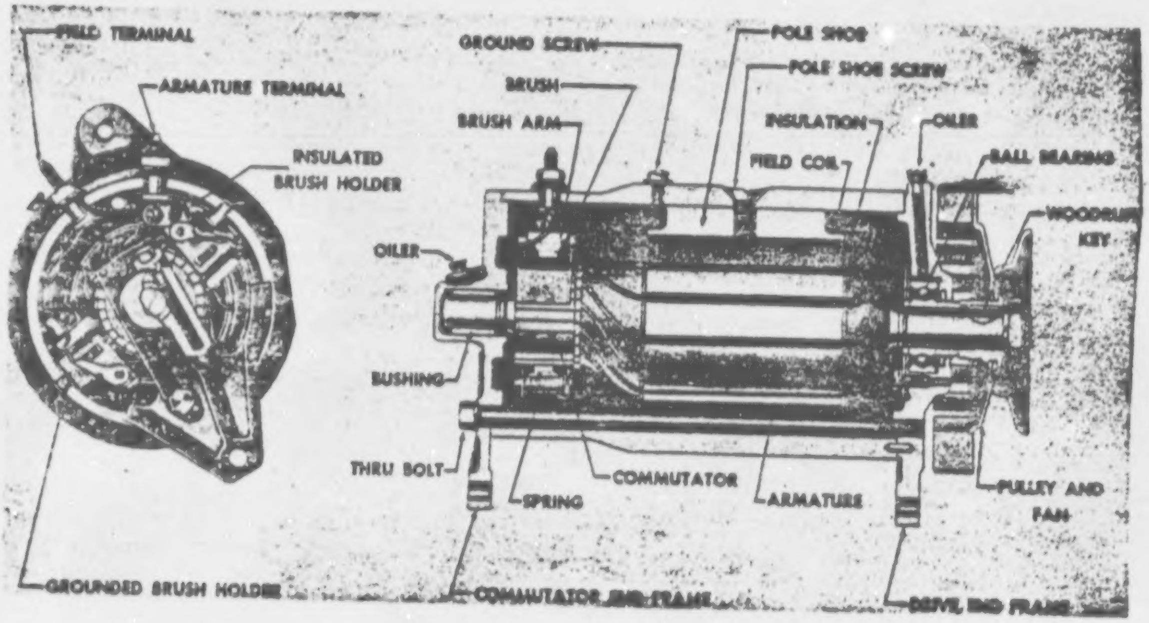
FIELD TERMINAL
ARMATURE TERMINAL
INSULATED BRUSH HOLDER
GROUNDED BRUSH HOLDER
GROUND SCREW
BRUSH
BRUSH ARM
OILER
BUSHING
THRU BOLT
SPRING
COMMUTATOR
ARMATURE
COMMUTATOR END FRAME
POLE SHOE
POLE SHOE SCREW
INSULATION
OILER
FIELD COIL
BALL BEARING
WOODRUFF KEY
PULLEY AND FAN
DRIVE END FRAME

Figure 96. Sectional View of Shunt Type Generator.

The automotive generator, figure 96, consists of the pulley, fan, drive end frame, pole shoes, field coils, armature, commutator, and brushes. There are different types of generators in use for different vehicles. The generator used must do the job required of it. The normal electrical load on a vehicle will determine the capacity of the generator. Also, other factors, such as the operating conditions, will determine the design of the generator.

THE DC GENERATOR

The generator is an electromechanical machine. This machine changes the mechanical power from the engine into electrical energy for the vehicle's battery and accessories. Simply stated, the generator produces electricity. The generator is operated or driven by the vehicle engine's fan belt.

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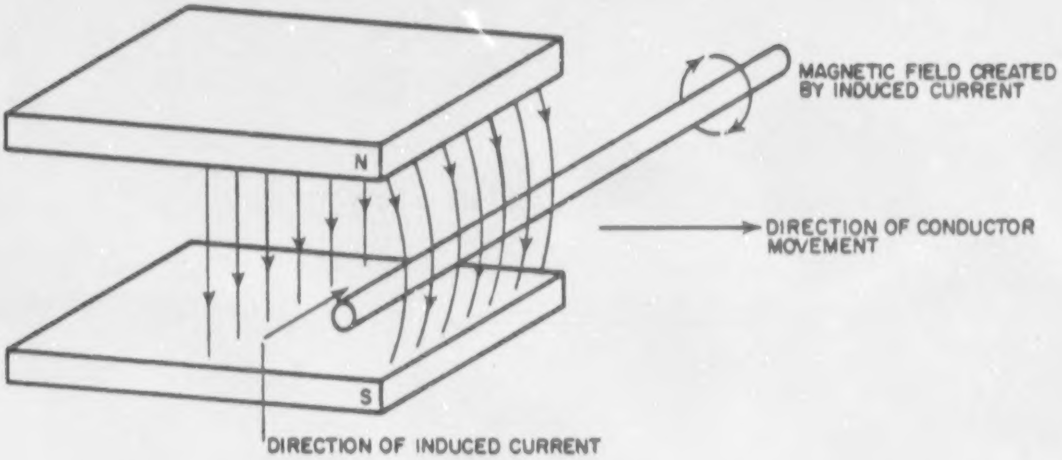
MAGNETIC FIELD CREATED BY INDUCED CURRENT
N
DIRECTION OF CONDUCTOR MOVEMENT
S
DIRECTION OF INDUCED CURRENT

Figure 97. Conductor Moving Through a Magnetic Field.

We can produce or generate electricity with magnetism. This is called electromagnetic induction. Generator operation is based on this principle of electromagnetic induction. Electrical pressure, known as voltage, is generated whenever any conductor is moved at right angles through a magnetic field. If a closed conductor is moved in the direction shown in figure 97, voltage will be induced into the conductor and cause current to flow in the direction shown.

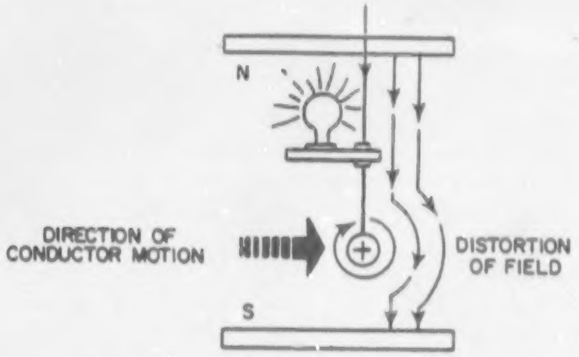
N
DIRECTION OF CONDUCTOR MOTION
DISTORTION OF FIELD
S

Figure 98. Side View of Magnetic Field.

Looking at this same magnetic field and conductor from the side, figure 98, the lines of force tend to wrap around the conductor. The lines of force are like rubber bands. When the conductor is moved through them, they tend to wrap around the conductor. When a magnetic field goes around a conductor like this, it induces or forces voltage into the conductor. If the conductor is then closed to form a complete circuit, the induced voltage will cause a current to flow.

In summary, we need three things to produce electricity by mechanical means. These three things are:

1. A magnetic field
2. A closed conductor
3. Motion

This is the principle of electromagnetic induction. It is one of the most important principles that there is in automotive electricity.

Operating Theory of the DC Generator

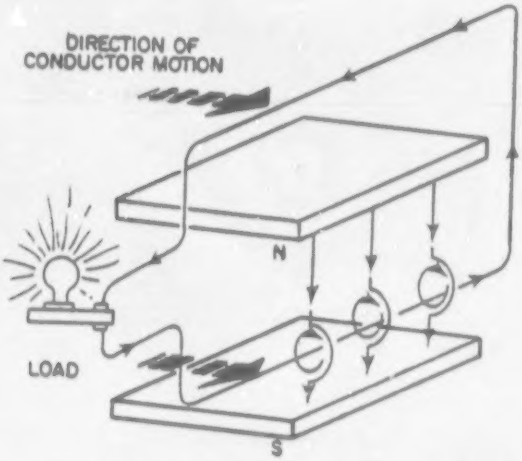

Figure 99. A Simple Generator.

The generator uses electromagnetic induction to produce electricity. Figure 99 shows a simple generator. A conductor is formed into a loop, with the ends connected to copper bars called commutator segments. A pair of brushes ride on these segments to pick up the current induced or generated in the loop. When the loop is revolved in a clockwise manner, as shown, current will flow around the loop and through the commutator segments, brushes, and lamp. When the loop is rotated 180 degrees, the two sides of the loop change position, but the current still goes through the lamp in the same direction. This is because the commutator segments have also changed position.

The Shunt Generator

The shunt generator is the most commonly used generator. A simple diagram of the shunt generator is shown in figure 100. The shunt generator has two circuits. One is called the field circuit and the other is called the charging or load circuit. These circuits are in parallel with each other. Remember, a shunt circuit is a parallel circuit.

THE MAGNETIC FIELD. The magnetic field in the generator is supplied by two magnets called pole shoes. These pole shoes are permanent magnets This means that there is a small amount of magnetism which remains in the

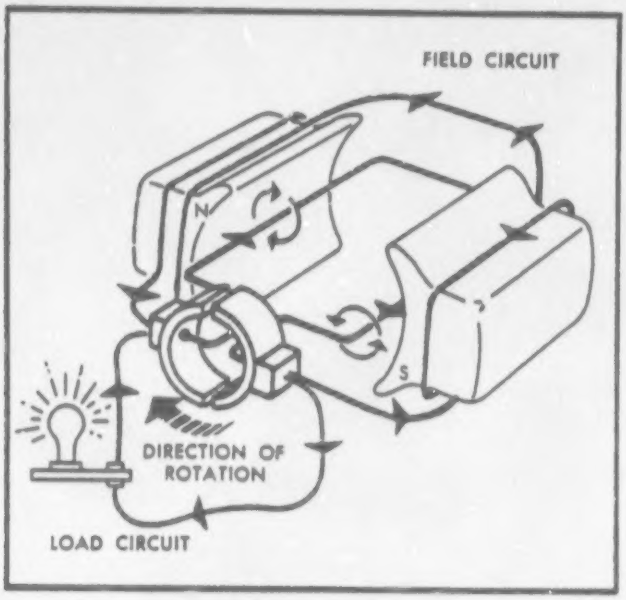
FIELD CIRCUIT
N
S
DIRECTION OF ROTATION
LOAD CIRCUIT

Figure 100. Wiring Diagram of a Shunt Generator.

pole shoes at all times. This small amount of magnetism is called "residual" magnetism. The residual magnetism, or remaining magnetism, is very small. However, the amount of magnetism is enough to cause some current to flow in the armature loops as they start to revolve. Residual magnetism is responsible for initial generator output. If there was no residual magnetism in the pole shoes, the generator would not work!

The magnets that form the magnetic field have a wire wrapped around them. These coils of wire are called field windings. These field windings make the pole shoes powerful electromagnets when current flows through the windings. These coils are wound and connected to the generator brushes in such a way that part of the output from the generator flows through them. Go back and look at figure 100 again.

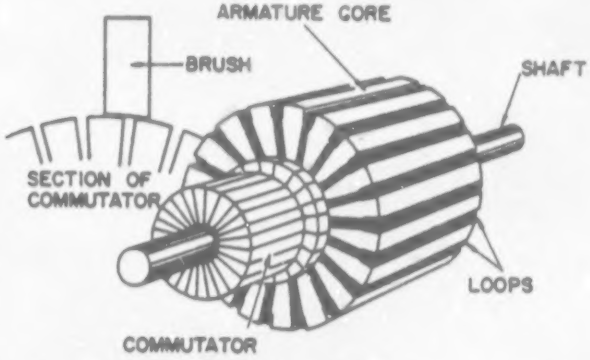
ARMATURE CORE
BRUSH
SHAFT
SECTION OF COMMUTATOR
LOOPS
COMMUTATOR

Figure 101. The Armature Assemblyl.

THE ARMATURE. We learned earlier in this chapter how voltage is generated and current flows from a generator with a single wire loop. This type of generator would be very unsatisfactory on today's vehicle because it would produce a very low output. To increase output, the automotive generator uses several loops of wire wound around a core. The whole assembly is called the armature, figure 101.

By using many loops of wire in the armature, there are more conductors which will pass through the magnetic field of the generator. When the number of conductors passing through the magnetic field is increased, the output of the generator will also be increased. Notice that there are several of these loops around the armature core, figure 101. Each end of these loops of wire is connected to a split ring segment, or commutator bar. All of these commutator bars make up the commutator.

The core around which the loops are wound is made from soft iron. It is made from soft iron to allow the lines of force of the magnetic field to easily pass through it. But because the core is a conductor, and it is moving in a magnetic field, a current is produced in it. This current is called an "eddy current." The result of this eddy current is heat--and heat can harm the generator. To prevent this from happening, the core is assembled from several discs of iron. This is called a laminated core. The laminated core reduces the eddy currents and the heat generated by the eddy currents. A fan is also placed on one end of the armature to pull cool air through the generator to reduce the heat produced by the manufacturing of electricity.

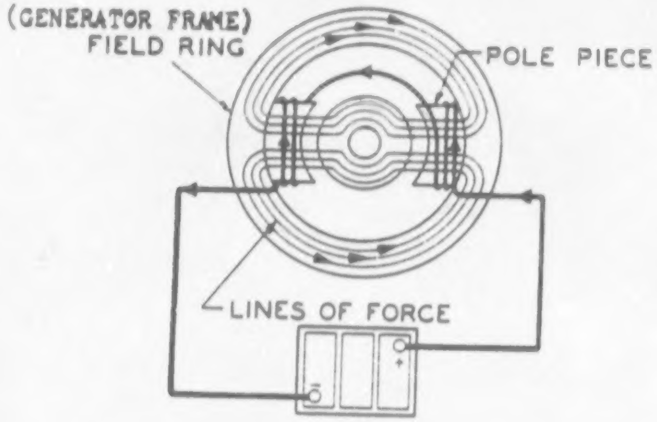

Figure 102. The Generator Field.

IRON FRAME HOUSING. The frame is important in the operation of the generator. Remember that magnetic lines of force will travel through soft iron more easily than air. The frame of the generator is made of iron. It allows the magnetic lines of force from the field to pass through it, figure 102. The frame then completes the magnetic circuit.

Generator Output

The current and voltage output of a generator depends upon the number of armature conductors, the strength of the magnetic field, and the speed at which the conductors cut through the magnetic field. The connections and number of the conductors are fixed by the designing engineer.

The strength of the magnetic field depends upon the number of windings in the field coil and amount of current flowing through the windings. This is the only condition that can be controlled after a generator has been built and installed. This is done by varying the current flowing through the field windings by means of various regulating devices.

The speed at which the conductors cut through the magnetic field is determined by the designing engineer, as was the number of conductors.

Generator Circuits

The shunt generator which is found on today's automotive vehicles may be either an "A" circuit generator or a "B" circuit generator. It is very important that you be able to identify the circuit you are working on. The only difference is in the way the field circuit is wired.

"A" CIRCUIT GENERATOR. Figure 103 shows how the field circuit of an "A" circuit generator is connected. The field circuit starts inside the generator at the insulated brush. The field circuit picks up its current directly from the armature. Field current flows around the field coils and then out the field terminal of the generator. It then goes to the generator regulator. Inside the regulator, the field current is directed to ground where it returns to the grounded brush of the generator. As the field circuit is grounded in the regulator, the "A" circuit is said to be externally grounded.

"B" CIRCUIT GENERATOR. The field circuit wiring of a "B" circuit generator is shown in figure 104. The main difference from the "A" circuit is that the "B" circuit field starts inside of the generator regulator. The field circuit picks up its current from the charging circuit in the generator regulator. Field current leaves the regulator and goes in the field terminal of the generator. Field current then goes around the pole pieces in the generator and is grounded to the frame. The "B" circuit is said to be internally grounded.

> Note: Both the "A" and "B" circuit generator systems do the same job. The only difference is how the field circuit is completed. Some test procedures are different for the two circuits, so it is necessary to determine which circuit is being worked on. The best and most reliable way to determine the circuit type is to refer to the manufacturer's maintenance manual or proper technical order.

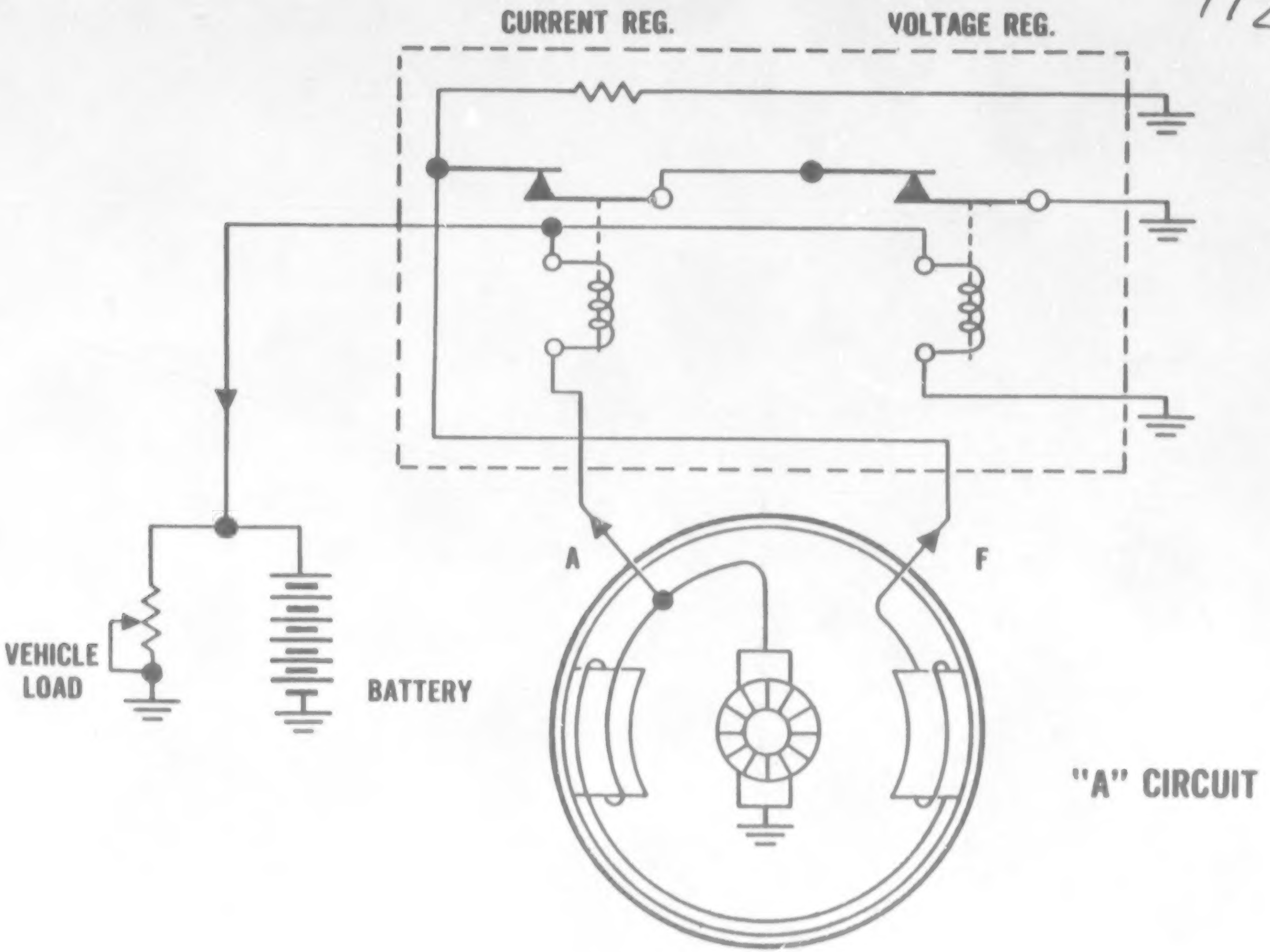
CURRENT REG.
VOLTAGE REG.
A
F
VEHICLE LOAD
BATTERY
"A" CIRCUIT

Figure 103. "A" Circuit Generator.

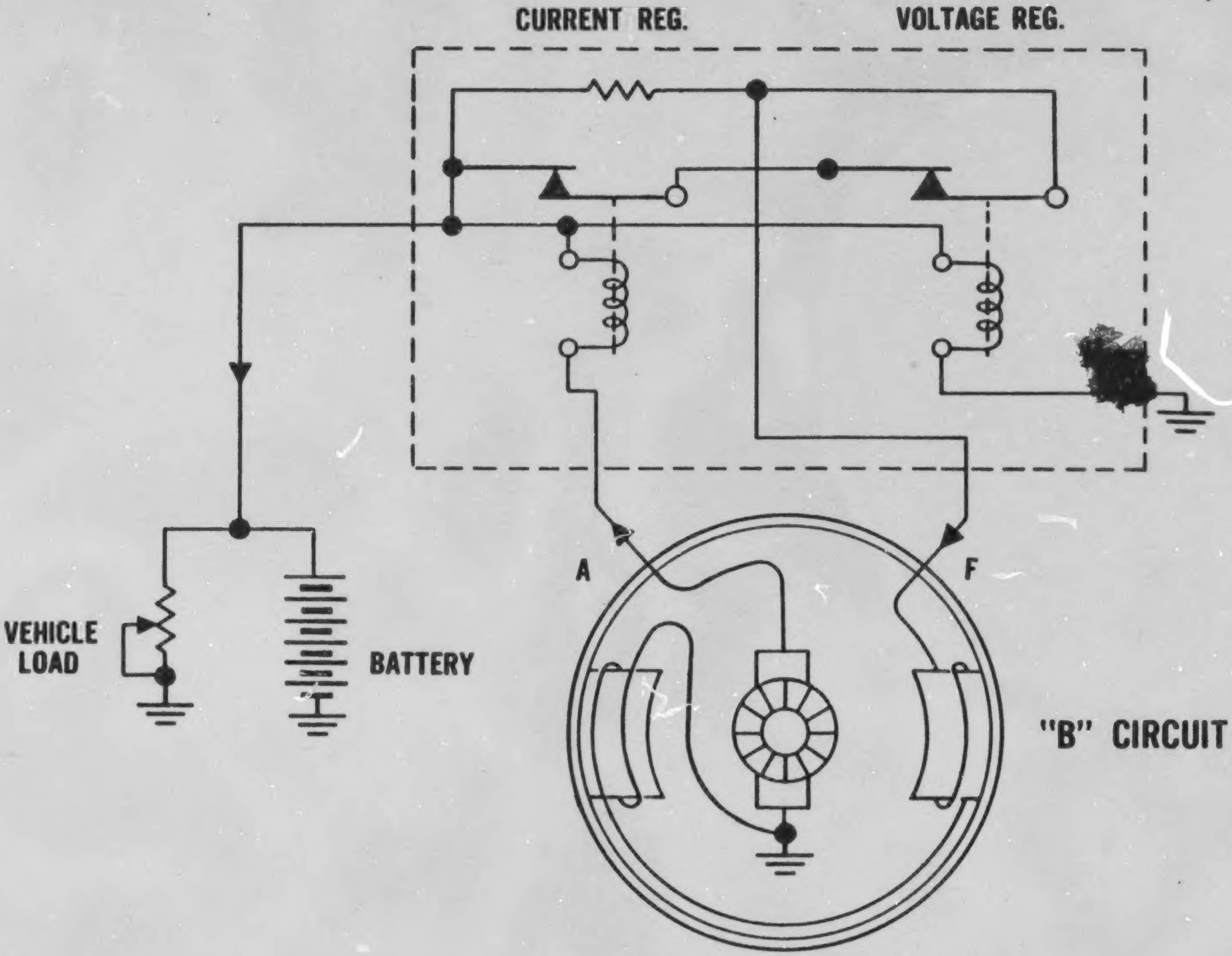
CURRENT REG.
VOLTAGE REG.
VEHICLE LOAD
BATTERY
A
F
"B" CIRCUIT

Figure 104. "B" Circuit Generator.

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THE GENERATOR REGULATOR

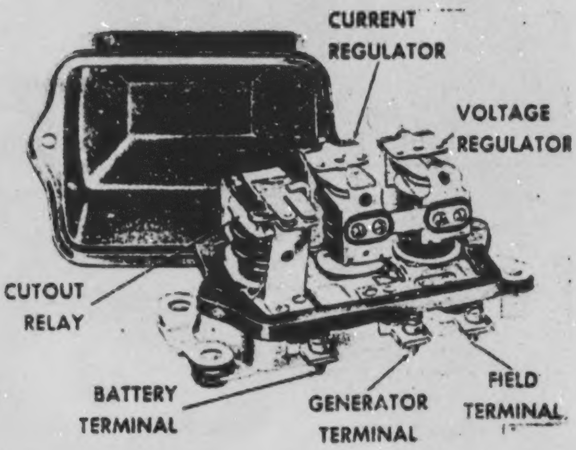

Figure 105. Typical Three Unit Regulator With Cover Removed.

The generator regulator is the brain of the generator charging system. Most generator charging systems use a three unit regulator similar to the one shown in figure 105. There are three main units in this regulator. These units are the cutout relay, current regulator and voltage regulator. Each unit has a separate job to do. The cutout relay must keep the generator and battery working together. The voltage regulator must control or limit the maximum voltage output of the generator. The current regulator must keep the current output of the generator within a safe limit.

Cutout Relay

As stated before, the cutout relay must keep the battery and generator working together. Whenever generator voltage is higher than battery voltage, the cutout relay connects the generator to the battery. This lets the generator recharge the battery. When the generator is stopped or when generator voltage is low, the cutout relay is open. This prevents the battery from discharging itself through the generator.

CONSTRUCTION OF THE CUTOUT RELAY. The cutout relay, figure 106, has two windings. One is a series winding of a few turns of heavy wire. The other is a shunt winding of fine wire connected directly to ground. The shunt winding is connected across the generator so that generator voltage is upon it al all times. The series or heavy winding is connected in series with the charging circuit. All generator output passes through the series windings. The relay core and windings are assembled onto a frame. A flat armature is attached to the frame by a flexible hinge. It is centered just above the core. When the generator is not operating, a set of contact points is held open by the tension of a spring.

OPERATION OF THE CUTOUT RELAY. When generator voltage builds up to a value great enough to charge the battery, the magnetic field build-up around the shunt winding is enough to pull the armature down so the contact points close, figure 106(A). Closing of the contact points complete the

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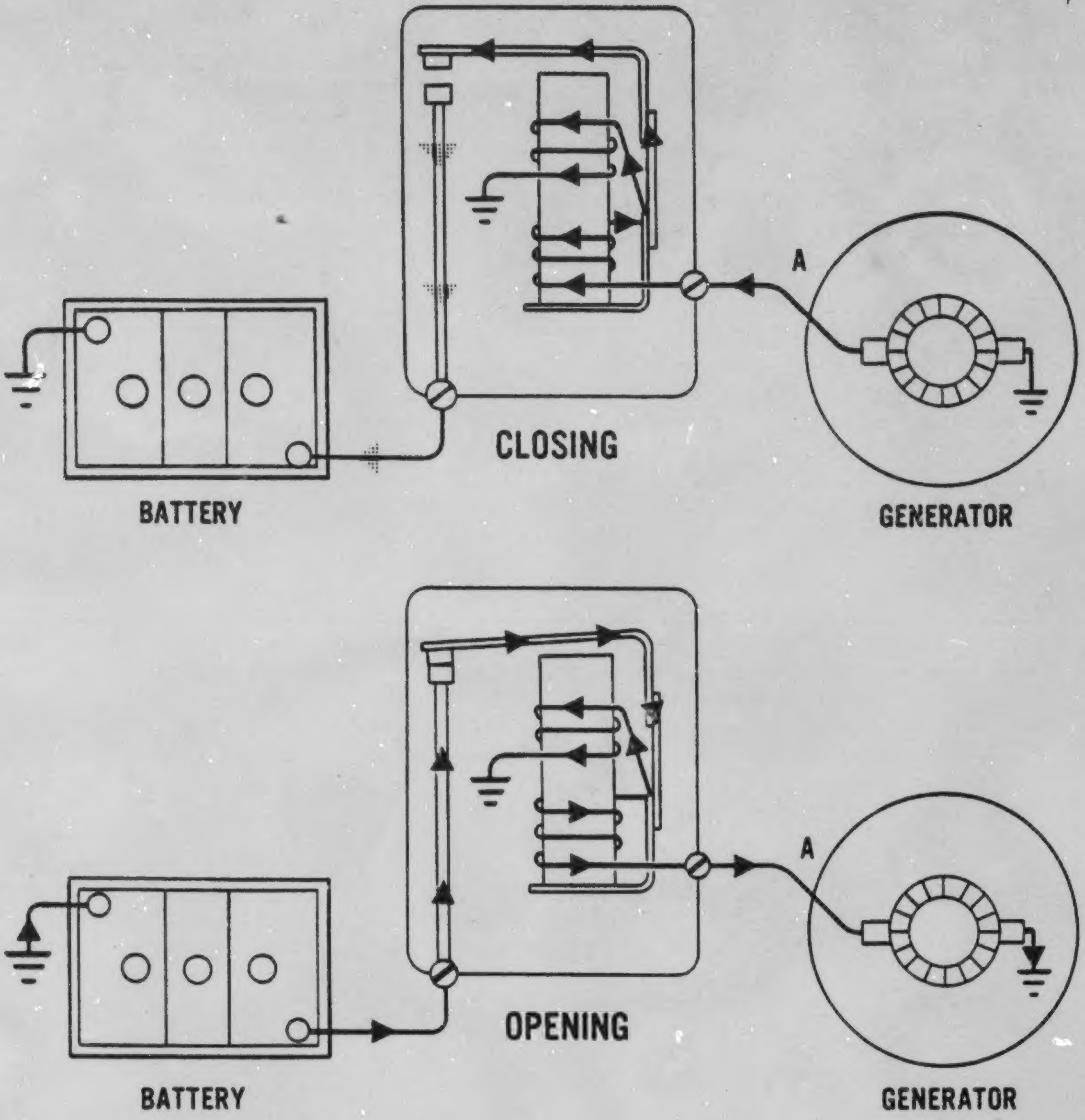

A
CLOSING
BATTERY
GENERATOR
A
OPENING
BATTERY
GENERATOR

Figure 106. Cutout Relay Action.

circuit between the generator and the battery. The current which flows from the generator to the battery passes through the series windings in a direction to add to the magnetism holding the contact points closed. However, if the generator slows down or stops, current begins to flow from the battery to the generator. This reverse flow of current through the series winding causes a reversal of the magnetic field of the series winding causes a reversal of the magnetic field of the series winding, figure 106(B). However, the magnetic field of the shunt winding does not reverse, figure 106(B). Instead of helping each other as before, the two windings now magnetically oppose each other. The magnetic field is now too weak to hold the points closed. The spring pulls the points open. This opens the circuit between the generator and the battery. Remember, generator voltage closes the cutout relay points. Reverse battery current and spring tension opens them.

Voltage Regulator

As the battery becomes charged, the generator voltage will increase to overcome the resistance of the fully charged battery. This would result in excessive generator voltage. Voltage is electrical pressure which causes current to flow. This high voltage can cause the battery to become overcharged (due to the high current flow), light bulbs to burn out and the accessories to be damaged (due to the high voltage). The purpose of the voltage regulator then is to prevent excessive voltage.

CONSTRUCTION OF THE VOLTAGE REGULATOR. The voltage regulator, figure 107, has a shunt winding consisting of many turns of fine wire. This winding is sensitive to voltage. The winding and core are assembled onto a frame. A flat steel armature is attached to the frame by a flexible hinge. The armature contains a contact point which is just beneath a stationary contact point. When the voltage regulator is not operating, the tension of a spring holds the armature so that the contact points are closed. The generator field circuit is completed to ground through these contact points.

OPERATION OF THE VOLTAGE REGULATOR. When generator voltage reaches the value for which the voltage regulator unit is set, the magnetic field produced by the winding overcomes the spring tension and pulls the armature down. This separates the contact points. A resistance is then placed into the field circuit. The generator field current and voltage are reduced. This reduces the generator voltage output to a safe limit. When generator voltage output is reduced to its safe limit, the magnetic field around the core of the voltage regulator is reduced also. When the magnetic field is weakened, the spring pulls the voltage regulator points closed. This directly grounds the generator field circuit. This allows the generator voltage and output to increase. The above cycle may be repeated at the rate of 50 to 200 times per second. This is a vibrating type voltage regulator.

Current Regulator

The amount of current that a generator will produce depends upon the demand of the vehicle's electrical system and the condition of the battery. If the load demand is low, generator current output will be low. If the load demand is high, the generator will try to put out current to equal the high demands. For example, when the battery is in a low state of charge and many accessories are turned on, there is a high current demand. The generator will try to equal this demand. This is fine unless the demand is more than the generator can safely

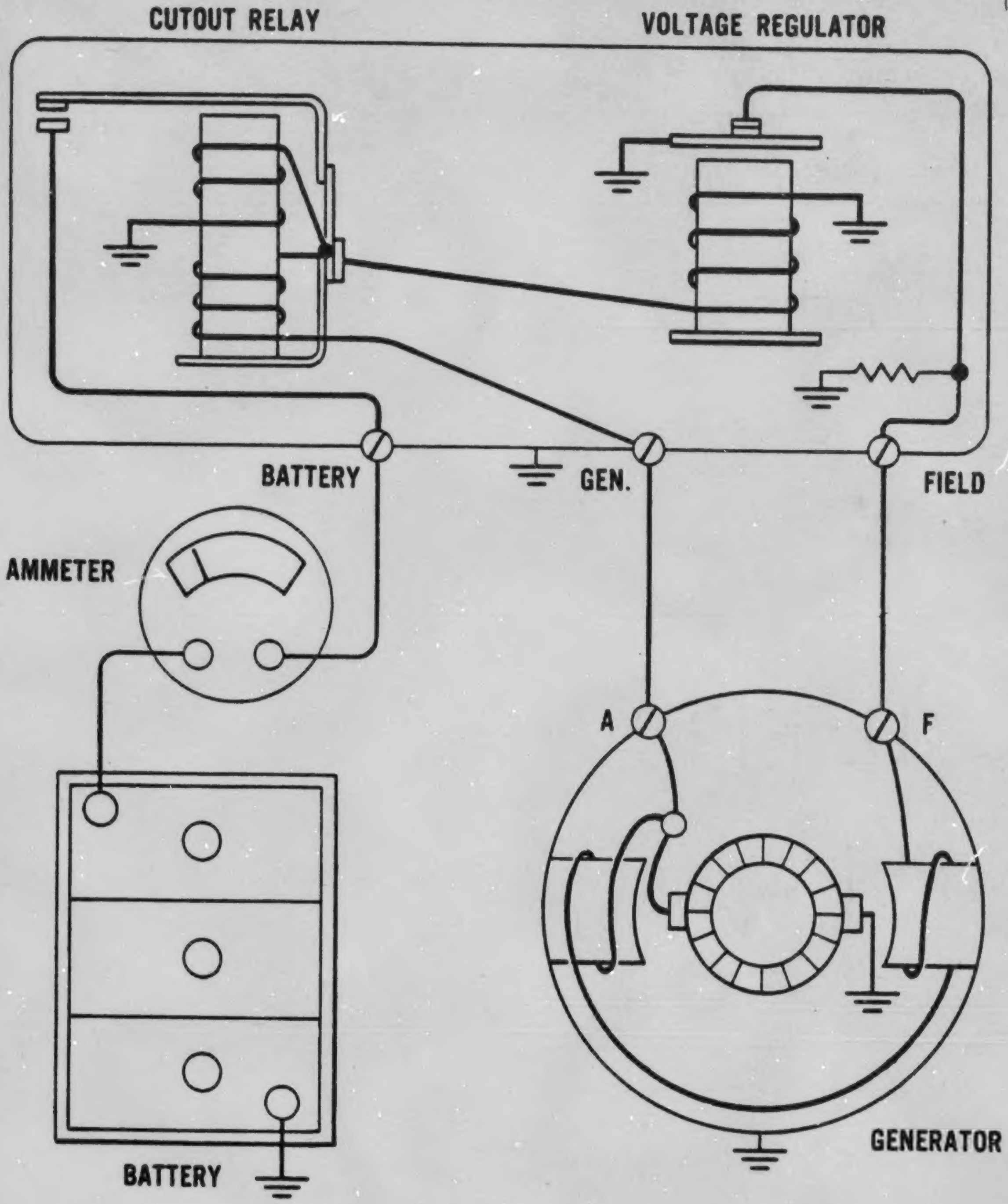

CUTOUT RELAY
VOLTAGE REGULATOR
BATTERY
GEN.
FIELD
AMMETER
A
F
BATTERY
GENERATOR

Figure 107. Voltage Regulator Action.

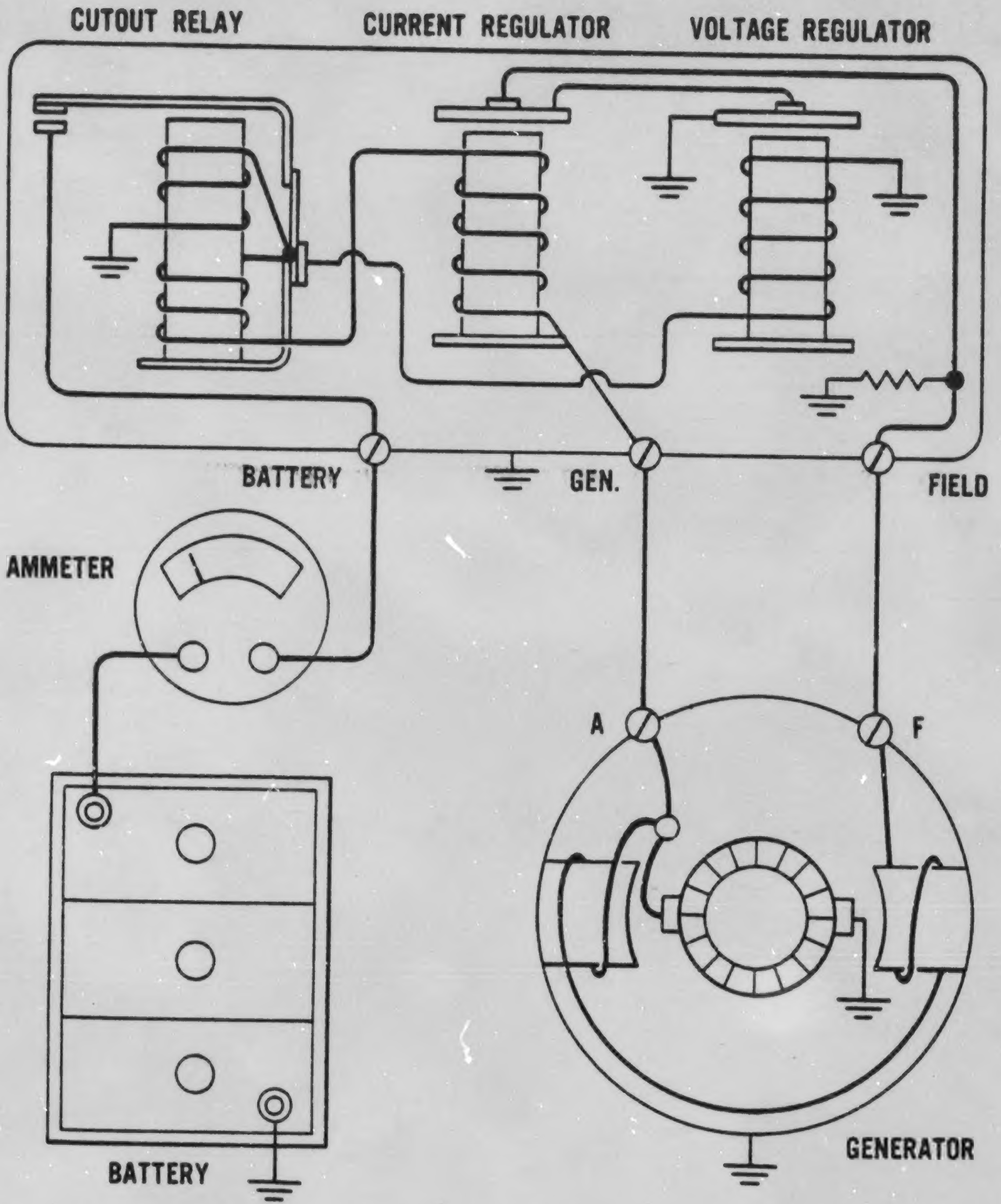

CUTOUT RELAY
CURRENT REGULATOR
VOLTAGE REGULATOR
BATTERY
GEN.
FIELD
AMMETER
A
F
BATTERY
GENERATOR

Figure 108. Current Regulator Action.

produce. Therefore, it is necessary to regulate or limit the current output of the generator. The current regulator prevents the generator from burning itself up.

CONSTRUCTION OF THE CURRENT REGULATOR. The current regulator, figure 108, has a series winding of a few turns of heavy wire. This winding carries all generator output. The winding and core are assembled on a frame. A flat steel armature is attached to the frame by a flexible hinge. It is just above the core. The armature has a contact point which is just below a stationary contact point. When the current regulator is not operating, the tension of a spring holds the contact points closed. When the points are closed, the generator field circuit is completed to ground through the current regulator points.

OPERATION OF THE CURRENT REGULATOR. When the generator current output reaches the value for which the current regulator is set, the magnetic field around the series winding pulls the contact points open. A resistor, located on the base of the regulator, is then put into the field circuit. This reduces field current and results in lower generator current output. This causes the magnetic field around the current regulator winding to become weaker. The spring then pulls the contact points closed again. When the contact points close, the generator field is directly grounded. The generator output again increases. This cycle is repeated many times a second, and limits the generator current so as not to exceed its rated output.

Differences Between "A" and "B" Circuit Regulators

The above discussion has been of what takes place in the operation of the "A" circuit regulators. The "B" circuit regulators operate in much the same manner. In the "B" circuit however, the field circuit begins in the regulator. Field current passes through the regulating units or the resistor and then goes to ground in the generator. "A" and "B" circuit regulators are different, but both work on the same principles.

Note: "A" and "B" circuit regulators are not interchangeable. Be sure to replace with a regulator of the same circuit type.

POLARITY

Polarity is a term used to describe a direction of current flow in the charging system. In the DC charging system, output from the generator should be from the insulated brush to the positive post of the vehicle battery. It then returns from the battery to the generator by way of the vehicle frame. Which way current flows from the generator depends upon the position of the pole shoes in the generator and which way current flows through the field windings. If the pole shoes are installed backwards in the generator, or current flowed accidentally through the field coils in the wrong direction, the generator would become improperly polarized with respect to the vehicle battery.

Effects of Improper Polarity

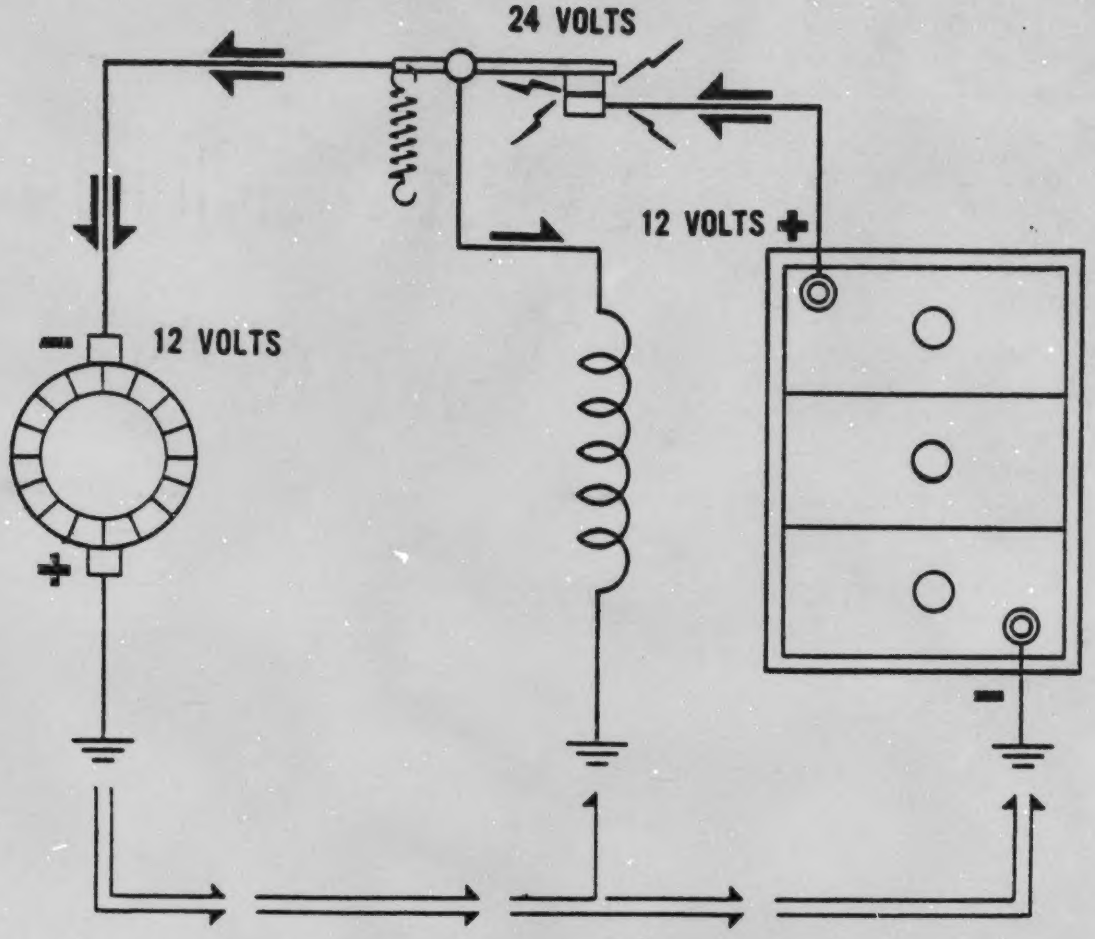


Figure 109. Effects of Reversed Generator Polarity.

In a charging system of the correct polarity, generator voltage will build up until it is high enough to charge the battery. The cutout relay points will then close and the generator will recharge the battery. If the generator polarity is reversed, the generator voltage would also be reversed. This causes generator output to flow in the wrong direction from the generator. The generator and battery are now connected in series. When the cutout relay points close, generator and battery voltage together pass through the points. Refer to figure 109. This will cause the cutout relay points to burn and eventually weld together. This allows the generator and battery to be connected together at all times. In a short time the battery may become completely discharged. The generator armature may also become burned and have to be replaced.

Correcting Generator Polarity

Correcting generator polarity is easy. It is often called "polarizing the generator." It assures that there is residual magnetism of the correct polarity in the generator. This is done by allowing a current to flow through the field coils in the proper direction. The magnetic field set up by the coils will properly magnetize the generator pole pieces. Remember however that there is a difference in the wiring of the field coils of the "A" and "B" circuit generators. Therefore, there is a different procedure for each circuit. On both systems, polarizing is easily done at the regulator.

> Warning: Because of the danger of the pole shoes accidentally becoming magnetically reversed when bench testing a generator, the generator must be polarized when it is installed on the vehicle. It is polarized after the leads are connected but before the engine is started.

POLARIZING THE "A" CIRCUIT GENERATOR. The field of the "A" circuit generator starts inside the generator. It grounds externally in the regulator after passing through the current and voltage regulator points. To avoid damage to these contact points, first disconnect the field lead at the regulator. Connect it to a good ground on the vehicle frame. To polarize the generator, momentarily touch a jumper lead between the "BAT" and "GEN" terminals of the regulator, figure 110. This allows a momentary flow of current through the field coils of the generator. This correctly polarizes it.

POLARIZING THE "B" CIRCUIT GENERATOR. This type of generator is polarized by disconnecting the field lead from the regulator and momentarily touching this lead to the "BAT" terminal of the regulator, figure 111. Battery current will then go from the battery terminal, through the field wire and field coils to ground. This momentary current is enough to polarize the generator.

> Warning: Failure to remove the field lead from the regulator will result in burned regulator points. Never use a jumper lead between the "BAT" and "F" terminals of the regulator.

Regulator Polarity

Some regulators are designed for use on a negative ground system. Others are for positive ground systems. The difference is in the design of the regulator points. Using a regulator of the wrong polarity will cause the current and voltage regulator points to pit and burn. This will shorten the life of the regulator. The model number, voltage, and polarity are often stamped on the base of the regulator. Make sure the correct polarity regulator is used.

TESTING OF THE DC CHARGING SYSTEM

As with any of the complex systems on the modern vehicle, malfunctions do occur. When trouble with the charging system is encountered, it can be found by a systematic test procedure. Because there are so many different types of vehicles on the road, it would be impossible to include

182

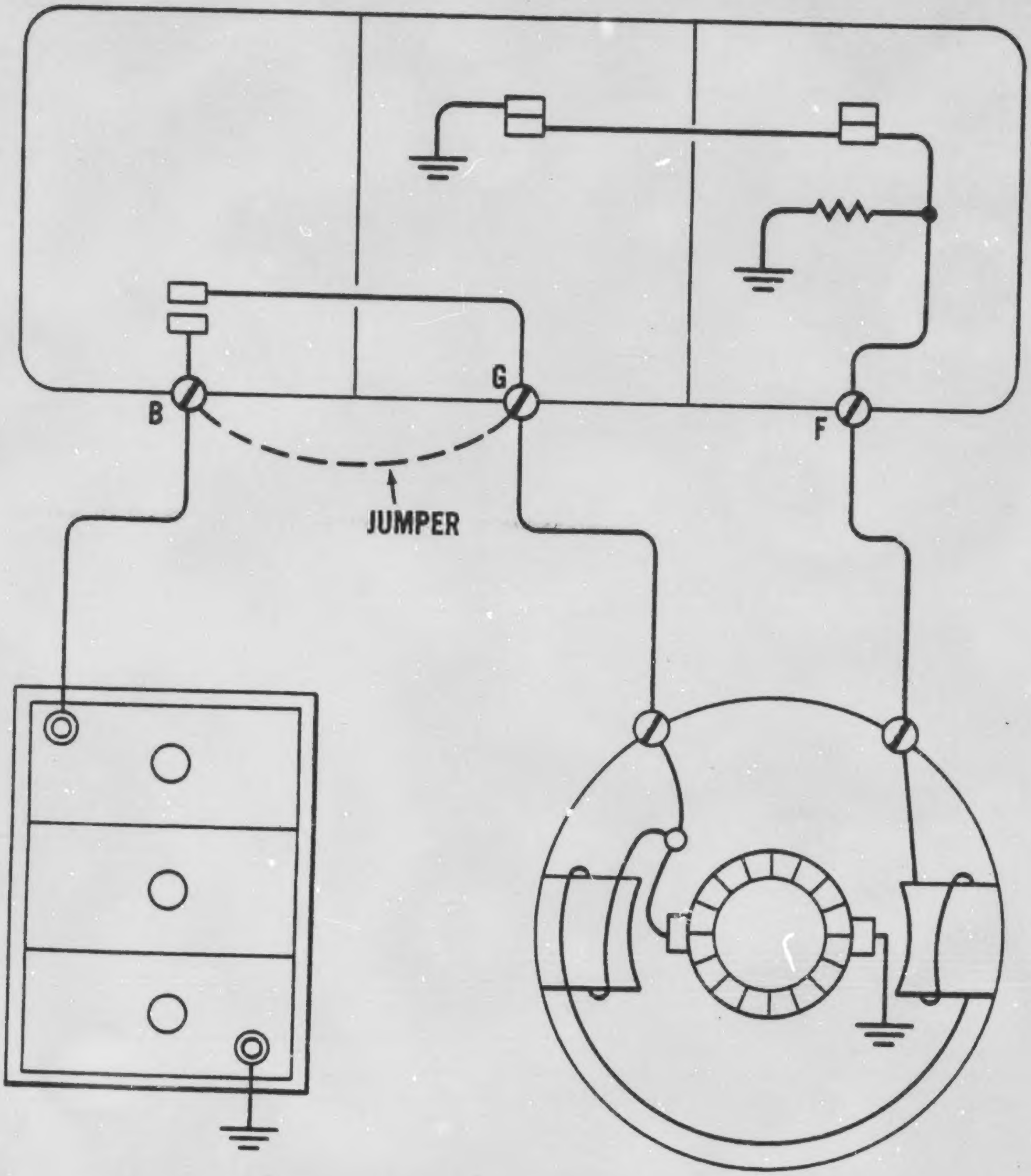


Figure 110. Polarizing the "A" Circuit Generator.

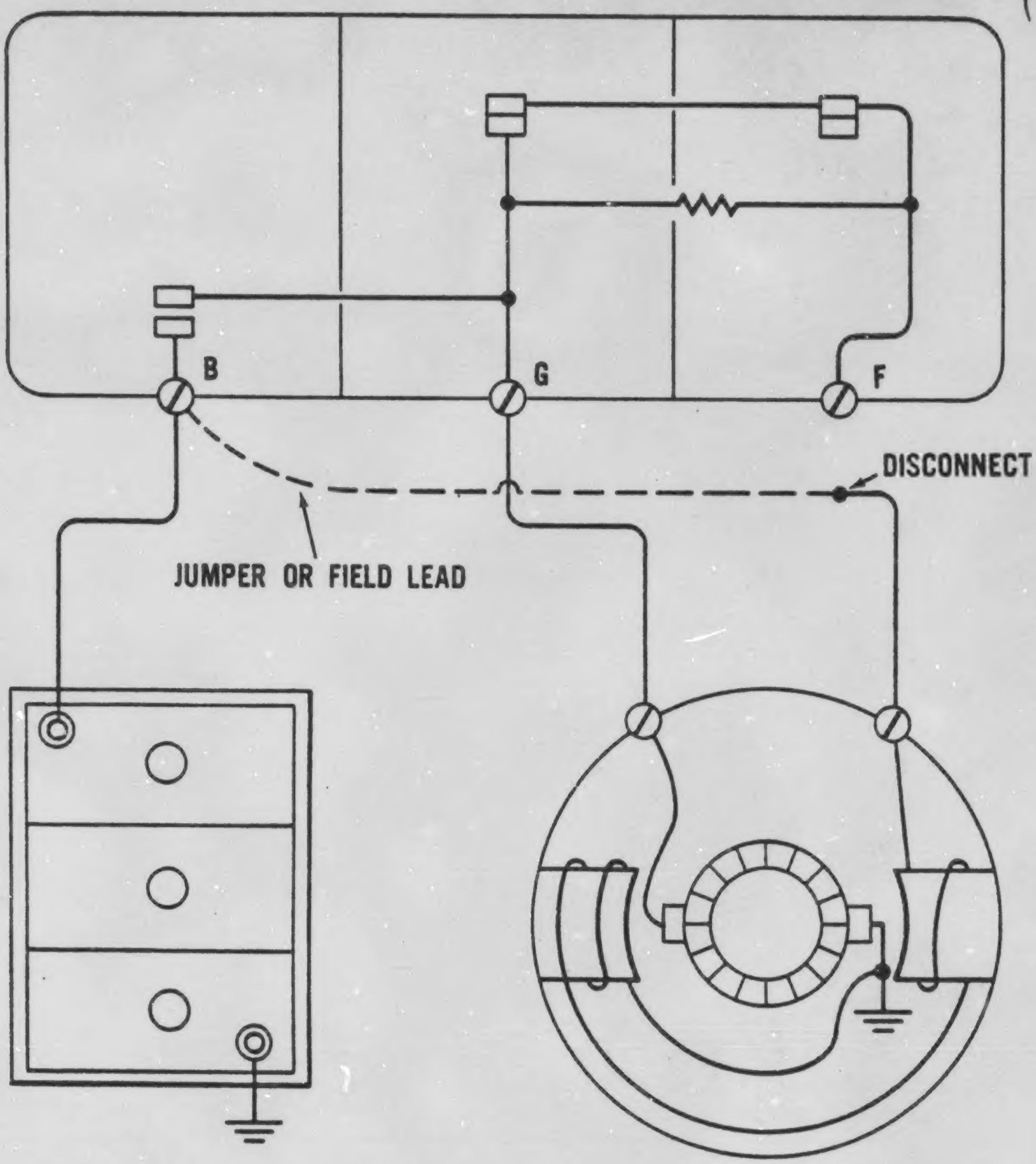

B
G
F
DISCONNECT
JUMPER OR FIELD LEAD

Figure 111. Polarizing the "B" Circuit Generator.

all test procedures. The following information concerning test procedures is general. Always consult the proper maintenance manual or technical order.

Visual Inspection

Many charging system troubles can often be found by a good visual inspection. Check the generator drive belt and all vehicle wiring. Make sure they are in good condition. Don't forget the battery! It must be in a good state of charge.

By-Passing Regulation

The regulator can be eliminated from the charging system to determine if it or the generator is at fault. With the regulator by-passed, if the generator produces voltage and current to specifications, the regulator is at fault. If the generator will not charge with the regulator by-passed, the generator must be removed and repaired. With the regulator by-passed, generator output is controlled only by the speed of the engine. Again, as there are two types of generator circuits, there are two ways to by-pass the regulator.

BY-PASSING THE "A" CIRCUIT CURRENT AND VOLTAGE REGULATORS. To by-pass the "A" circuit current and voltage regulator units, simply disconnect the field wire from the "F" terminal of the regulator and connect it to a good ground.

BY-PASSING THE "B" CIRCUIT CURRENT AND VOLTAGE REGULATORS. The "B" circuit regulator units are easily by-passed by disconnecting the field wire from the "F" terminal of the regulator and attaching it to the armature ("ARM") terminal of the regulator.

> Caution: By-passing the regulator should be done for testing purposes only. Normal operation of the vehicle with the regulator by-passed will result in severe damage to the entire electrical system.

BY-PASSING THE CUTOUT RELAY. The following procedure is used to by-pass the cutout relay. This procedure is the same for both "A" and "B" circuit charging systems. To by-pass the cutout relay, connect a jumper wire between the battery and armature (or generator) terminals of the regulator. With all units bypassed, it can now easily be determined if the generator or regulator is at fault.

> Caution: The engine must be running when the cutout relay is by-passed. If the engine is not running, the battery will become discharged and damage to the wiring and generator may result.

GENERATOR OUTPUT TEST. The manufacturer designs a generator to have a certain output. The rated output must be checked. If the generator fails to reach its rated output it must be removed and repaired or replaced.

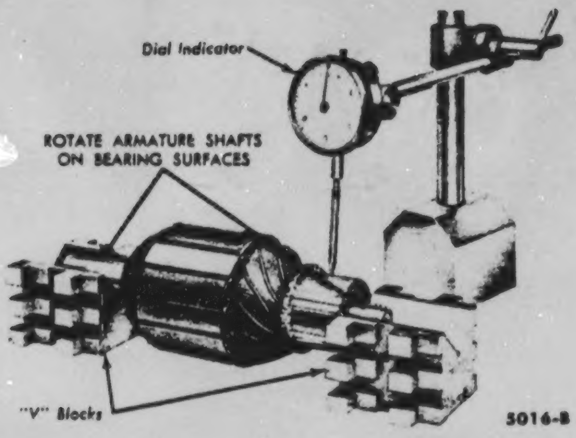

Dial Indicator
ROTATE ARMATURE SHAFTS ON BEARING SURFACES
"V" Blocks
5016-B

Figure 115. Commutator Runout Check.

it down in a lathe or with a turning and undercutting tool, figure 116. Remove no more copper than necessary to clean up the commutator.

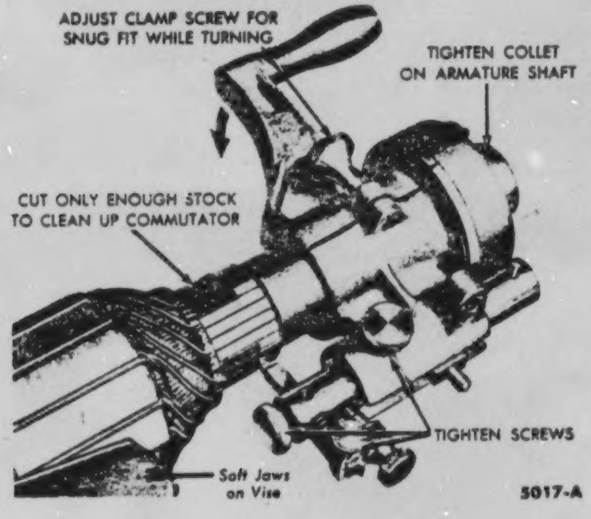

ADJUST CLAMP SCREW FOR SNUG FIT WHILE TURNING
TIGHTEN COLLET ON ARMATURE SHAFT
CUT ONLY ENOUGH STOCK TO CLEAN UP COMMUTATOR
TIGHTEN SCREWS
Soft Jaws on Vise
5017-A

Figure 116. Generator Commutator Turning.

After the commutator is turned down, undercut the mica between the bars 1/32 inch below the copper, using the undercutting tool as shown in figure 117. Figure 118 illustrates samples of proper and improper undercutting. Polish the commutator with #00 or #000 sandpaper to remove all burrs. Brush all particles of copper from the mica insulation between the commutator segments.

Field Coil Tests

The field coils should be inspected for bare insulation and broken wires. The coils are checked for unwanted grounds, opens, shorts, and excessive resistance. Procedures for testing the field coils can be found in applicable technical manuals.

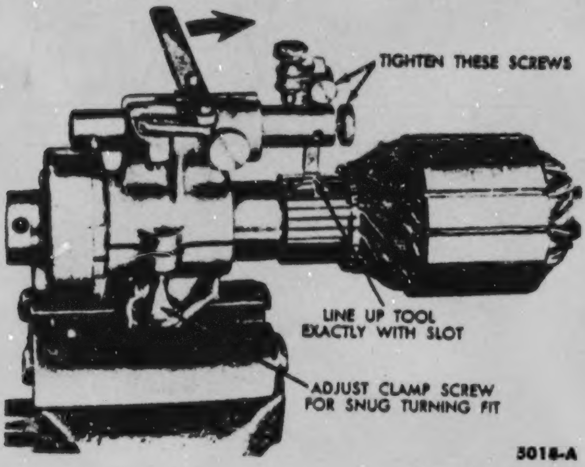

TIGHTEN THESE SCREWS
LINE UP TOOL EXACTLY WITH SLOT
ADJUST CLAMP SCREW FOR SNUG TURNING FIT
5018-A

Figure 117. Generator Commutator Undercutting.

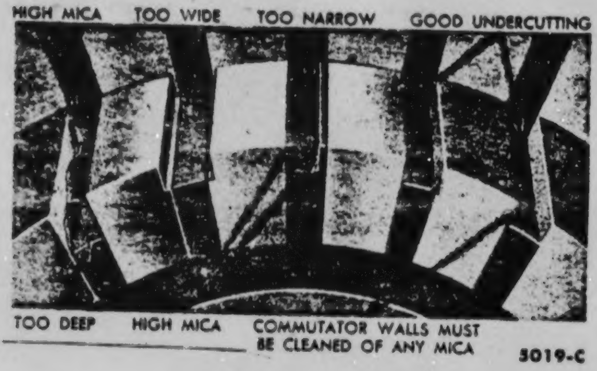

HIGH MICA
TOO WIDE
TOO NARROW
GOOD UNDERCUTTING
TOO DEEP
HIGH MICA
COMMUTATOR WALLS MUST BE CLEANED OF ANY MICA
5019-C

Figure 118. Examples of Proper and Improper Undercutting.

Brushes and Brush Holders

The brushes should be replaced when they are 1/2 their original length. Brush holder spring tension should also be checked with a spring tension gage. Holders not meeting specifications should be replaced.

REGULATOR MAINTENANCE

Electrical test and adjustments of the regulator have been stated already. However, there are some service procedures in addition to the electrical adjustments mentioned previously.

Mechanical Adjustments

These adjustments consists of point alignment, point gap, and air gap. Usually these adjustments are made at the time of manufacture and need never be changed. However, if adjustments are needed, consult the applicable technical publication for procedures and specifications.

Cleaning of Contact Points

Oxidized or burned points can cause resistance. If the points are pitted for any reason they must be cleaned before any electrical adjustments are made. Never use emery cloth or sandpaper to clean the points. Manufacturers recommend different methods for cleaning points. Some recommend a special fine cut contact file. Others recommend a special spoon or riffle file as shown in figure 119.

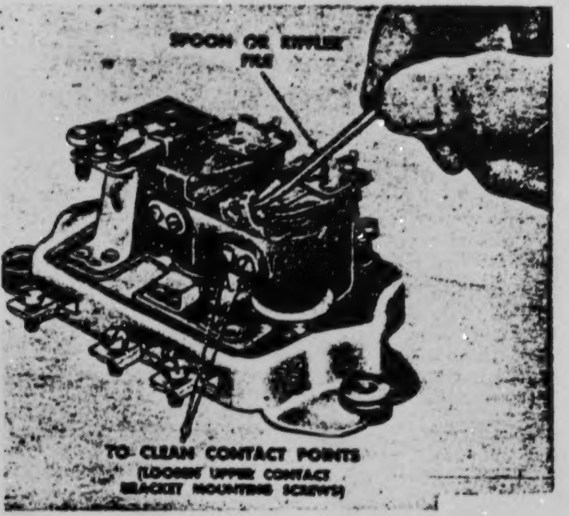


Figure 119. Using Spoon or Riffler File to Clean Flat Contact Points in the Regulator.

SUMMARY

Although this material has been very general in nature, if it is thoroughly studied, the purpose, construction, and operating principles of the DC charging system should be easily understood. The test procedures and specifications will be found in the technical publications, commercial manuals, and student workbooks. This literature will be available for your use during the time you will be using the test equipment and actually making the tests on the charging system components.

QUESTIONS

1. What three basic units does the DC charging system consist of?
2. Why is the generator regulator employed in the charging system?
3. What is the purpose of the voltage regulator (limiter)?
4. What is the purpose of the current regulator (limiter)?
5. What is the purpose of the cutout relay?

6. The iron core of the generator acts as one large conductor which actually generates voltage within the core itself. This action results in current flow. What is this current flow called?

7. What devices are used on generators to carry off the heat?

8. Why is it so important that the heat be removed from the generator?

9. What is the basic principle of generation?

10. What are the three main functional sections of the DC generator?

11. How do the various regulating devices control the output of the generator?

12. What is the simplest method of controlling the generator output on the shunt type generator?

13. What are the two circuits in the shunt type generator?

14. What type of field circuits are used in the shunt type generator?

15. What is meant by the terms "full field" and "regulated field?"

16. What separates the contact points of the voltage regulator unit?

17. What holds the armature away from the core so that the points are in contact when the current regulator is not operating?

18. What is the purpose of the common resistor that is inserted in the field circuit when either the current or voltage regulator operates?

19. Why shouldn't the cutout relay points ever by closed by hand?

20. What is used to clean regulator contact points when they become burned or oxidized?

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-SG-305

AC CHARGING SYSTEM

OBJECTIVES

After completing this study guide and your classroom instruction, you will be able to explain the principles of operation, function and relationship of AC charging system components, and be able to use visual, auditory, operational means and test equipment to check, adjust and isolate malfunctions in the AC charging circuit.

INTRODUCTION

The charging circuit is comprised of electrical components that work together as a team to supply electrical power for the current consuming devices, such as ignition, lights, radio, windshield wiper motors, power seat and window motors, air conditioning and heater blower motors, cranking motors and many other devices.

The continual addition of electrically operated accessories in today's cars, plus more time spent in slow speed driving due to greater traffic congestion, has increased the need for a generator which is capable of developing a considerable output of electrical energy not only at slow car speeds, but also at engine idle speeds. To meet this increased demand for electricity during slow speed driving and at engine idle, the AC generator, or alternator, has been developed. It is small in size and light in weight, but high in performance and output.

The alternator is one of three members that make up the charging circuit. The other two members are the battery and the voltage regulator. The operation of these units should be well understood because poor functioning of individual units in the charging circuit may be affected by other units or wiring in the same circuit.

INFORMATION

Before starting the study of the alternator charging system, review the fundamentals of electricity and magnetism in Student Study Guide 3ABR47330-301 in the front of this book. Although you may find alternator systems manufactured by different manufacturers, such as Delco-Remy, Chrysler, Leece-Neville, Prestolite, and Motorola, the operating principles are all very similar. The design of the component parts may differ however. The Delco-Remy "Delcotron" is shown in figure 120, and the Chrylser alternator in figure 121. Note the similarities between them.

THE ALTERNATOR

The alternator or AC generator converts mechanical action from the engine into electrical energy. The voltage and current that it produces recharges the battery and supplies power to the electrical system. It is a lightweight, high performance electrical power plant.

The standard production alternator was designed to replace the standard production DC generator for improved low speed output. It was not

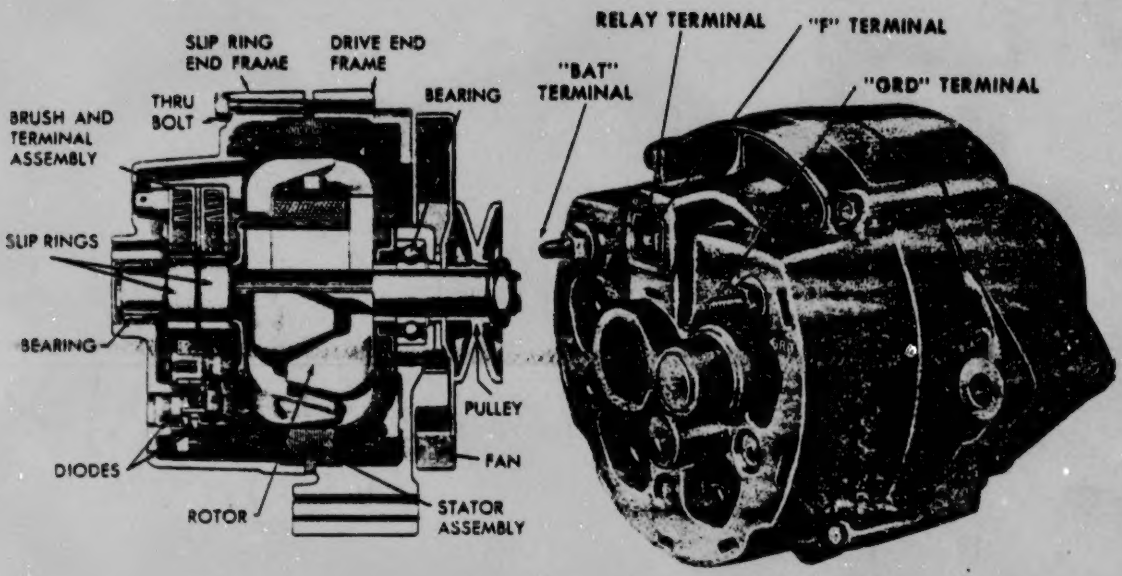

SLIP RING END FRAME
DRIVE END FRAME
THRU BOLT
BEARING
BRUSH AND TERMINAL ASSEMBLY
SLIP RINGS
BEARING
PULLEY
FAN
DIODES
ROTOR
STATOR ASSEMBLY
RELAY TERMINAL
"F" TERMINAL
"BAT" TERMINAL
"GRD" TERMINAL

Figure 120. 5.5" Series Delcotron.

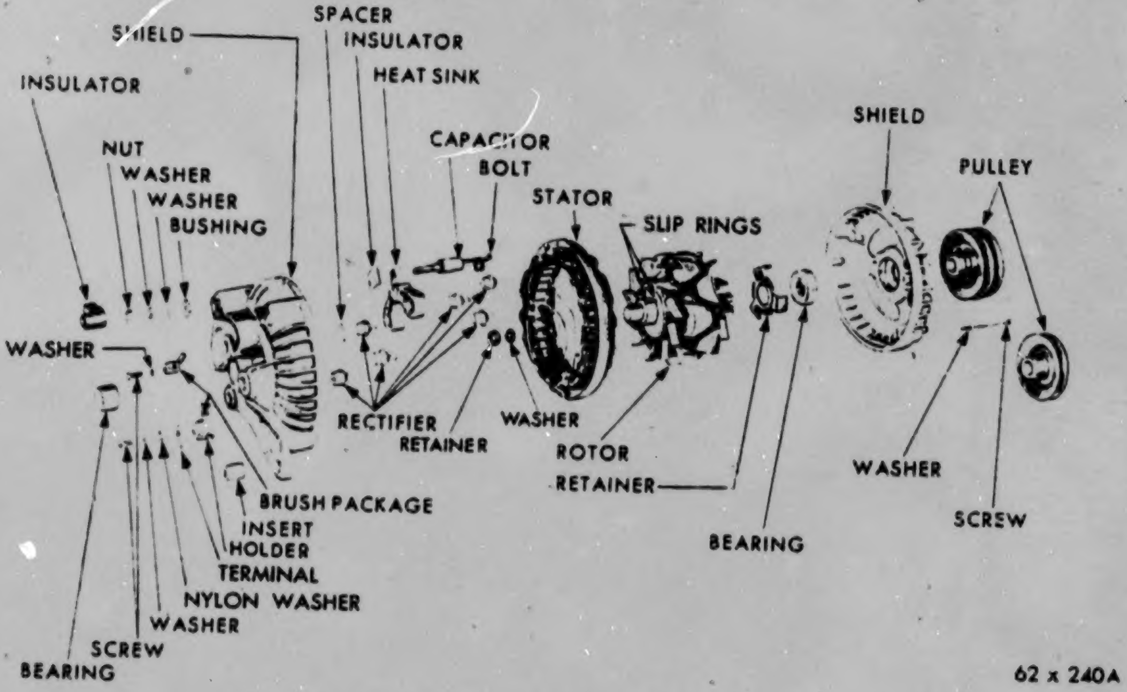

SHIELD
SPACER
INSULATOR
HEAT SINK
INSULATOR
NUT
WASHER
WASHER
BUSHING
CAPACITOR
BOLT
STATOR
SLIP RINGS
SHIELD
PULLEY
WASHER
RECTIFIER
RETAINER
WASHER
ROTOR
RETAINER
BEARING
WASHER
SCREW
BRUSH PACKAGE
INSERT
HOLDER
TERMINAL
NYLON WASHER
WASHER
SCREW
BEARING
62 x 240A

Figure 121. Alternator-Disassembled View (Chrysler)

designed to replace heavy duty generators needed to supply unusual demands such as those found where two-way radios and other special electrical equipment is used. A heavy-duty alternator is recommended under these special operating conditions.

Construction of the Alternator

The major components of the alternator are the two end frames, the rotor assembly, and the stator windings. As mentioned before, the design of the alternators may differ from manufacturer to manufacturer. Some of the factors which determine the design of the alternators are mounting, vibration, belt loading, current output, and other factors such as dirt, dust, and road splash.

END FRAMES. There are two end frames in the alternator, the drive end frame and the rectifier end frame, refer to figures 120 and 121. They are made of die-cast aluminum with air vents cast into the frames to aid in cooling the alternator. The two end frames are held together by through bolts. These are of equal length and size. The stator windings are "sandwiched" between the two end frames in the final assembly.

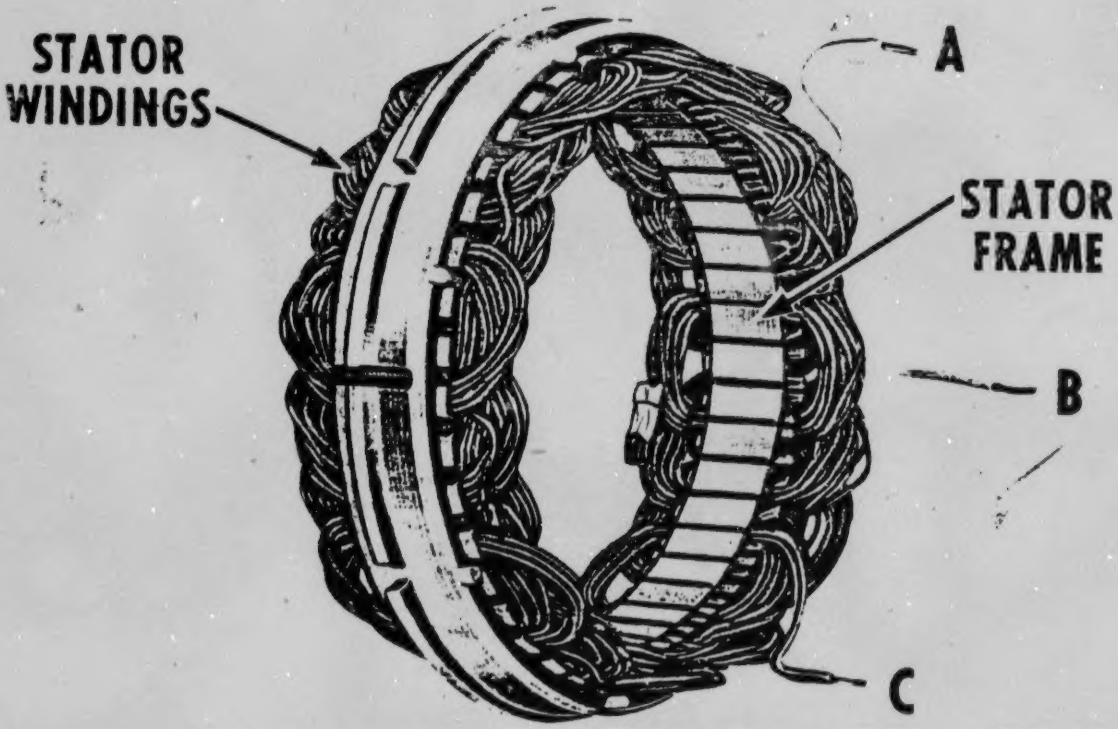


Figure 122. Stator Assembly.

STATOR WINDINGS. The construction of the stator is shown in figure 122. The stator assembly consists of three separate windings mounted on a laminated iron frame. One end of each of the three stator windings is connected to form a three-phase unit. This is known as a "Y" connection. The other end of each winding, called the terminal end, is connected to a pair of diodes--one positive and one negative. This pair of diodes is part of the rectifier assembly made up of a total of six diodes--three positive and three negative. The function and purpose of the diode rectifiers will be discussed in more detail later in this study guide.

There are two reasons for using three stator windings rather than just one or two windings. First, more voltage can be developed. The total voltage between any two terminal ends always is made up of the voltage of at least two individual windings which are connected in series. The second purpose of the three windings and the manner in which the windings are wound and overlapped in the stator frame is to provide a self-limiting control of current output. This happens through the principle of "inductive reactance." With this principle no external control of current is required. The need for a current regulator as in the DC charging system is eliminated.

THE ROTOR ASSEMBLY. The rotor assembly, figures 120 and 121, contains a doughnut shaped field coil wound onto an iron spool. The field coil is mounted between two iron segments with several interlacing fingers which are called "poles." These parts are held together by a press fit on the shaft. Two slip rings, upon which brushes ride, are mounted on one end of the rotor shaft and are attached to the leads from the field coil. An adequate cooling system carries away the heat generated in the windings and rectifiers from the current. The system consists of a fan or fans mounted on the rotor shaft. Cool air is drawn through the vents in the end frame, over the windings and then out of the alternator. The rotor assembly is supported in the drive end frame by a ball bearing and in the rectifier end by a roller bearing. These bearings are prelubricated and therefore do not require periodic lubrication. A grease filled reservoir in the drive end frame prolongs bearing life. The roller bearing in the rectifier end frame is permanently lubricated prior to assembly into the frame.

Production of Alternating Current

When the ignition switch is closed, current from the battery flows to the rotor. It passes through one brush, through the slip ring upon which the brush rides, and then through the field coil. After leaving the field coil, current flow continues through the other slip ring and brush before returning to the battery through the ground return path. This flow of electrical energy through the field winding is called field current and creates a magnetic field.

The magnetism created by this field current causes the poles on the rotor to become alternately North and South poles. It will be shown later that this magnetic field is used to produce alternating current in the stator windings.

For purposes of illustration, the most basic stator winding can be represented by a single loop of wire placed over the rotor, figure 123. Connecting the ends of the loop to a load such as a light bulb, as shown in figure 123, completes the circuit. As the rotor turns, the magnetic field from the North and South poles and the rotor cuts across each wire causing a voltage to be induced into the loop. Since the wire is influenced alternately by a north and then a south pole, the voltage produced is called an alternating voltage.

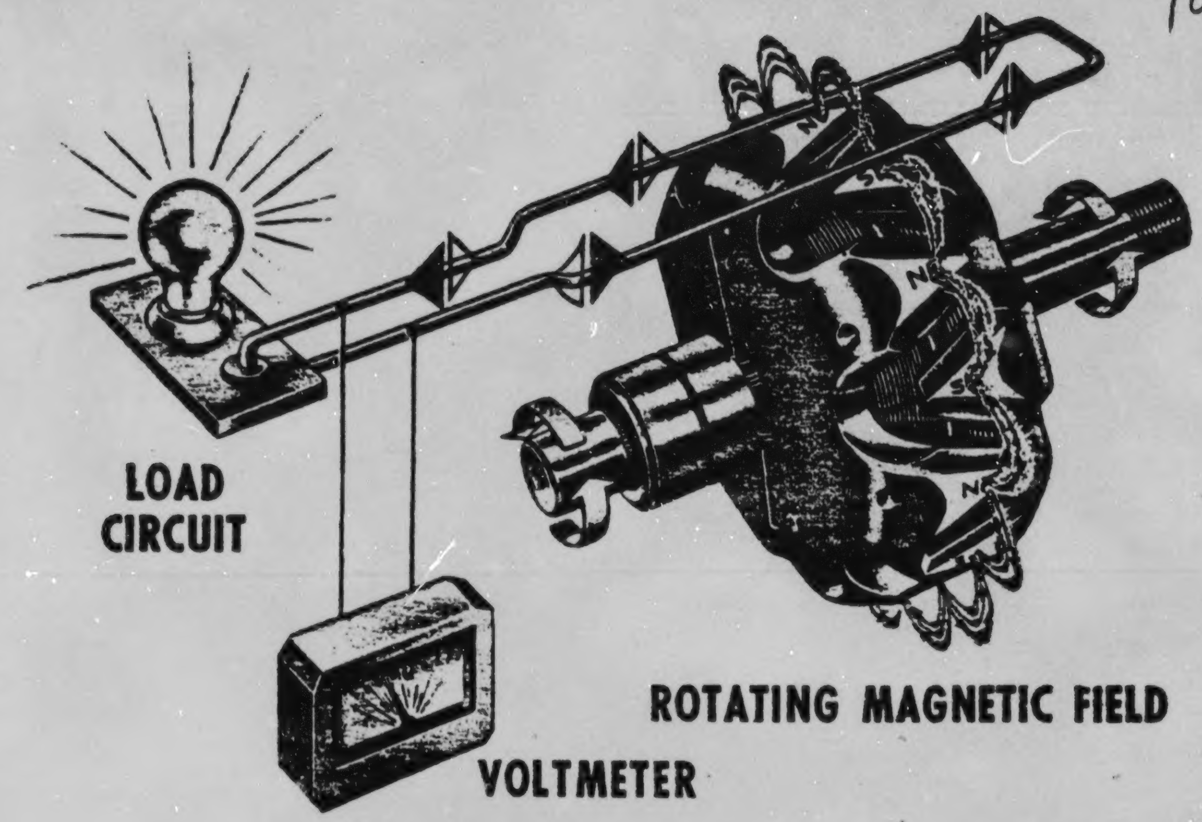

LOAD
CIRCUIT
N
S
N
S
N
ROTATING MAGNETIC FIELD
VOLTMETER

Figure 123. Basic Alternator Principle.

When a load, such as the light bulb, is connected to the ends of the loop, the alternating voltage produced will cause current to flow first in one direction, and then in the other through the bulb. This is called alternating current or AC current. If a meter is placed in the circuit the needle movement will show that the voltage will cause current flow first in one direction and then in the other.

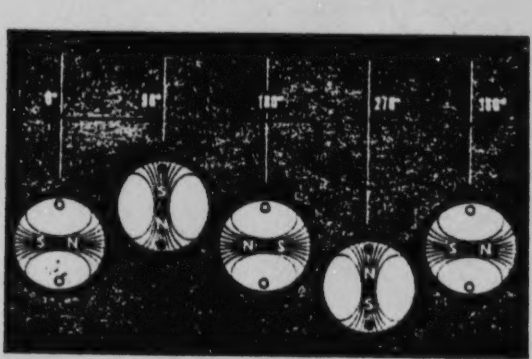

0°
90°
180°
270°
360°
S
N
S
N
N
S
N
S
S
N

Figure 124. Complete Sine Wave Generated Every 360 Degrees.

To illustrate further how an alternating voltage is produced, consider a simple two-pole permanent magnet type rotor and a stator that contains a single loop of wire, figure 124. Only the ends of the loop of wire are shown in the illustration.

Different positions of the rotor as it turns are shown in the diagrams below the horizontal solid line. The height of the curve above and below the horizontal line shows how much voltage is generated in the loop of wire as the magnetic lines cut across each side of the loop when the rotor turns. Positive voltage is shown above the solid horizontal line and negative voltage below the line. The entire curve shows the voltage output generated or the electrical pressure which can be measured across the ends of the wire, just as voltage can be measured across the terminal posts of the battery.

With the rotor in position (1) the voltage is zero. No voltage is being generated in the loop of wire because there are no magnetic lines of force cutting across the wire. As the rotor turns and approaches position (2), the rather weak magnetic field at the tip of the rotor starts to cut across the conductor, and a voltage is developed. As the rotor continues to turn, the voltage increases and reaches its maximum value, as shown above the horizontal line, figure 124, when the rotor reaches position (2). This maximum voltage occurs when the rotor is directly under each wire in the loop. It is in this position that the loop of the wire is being cut by the heaviest concentration of magnetic lines of force.

It should be noted in particular that the height of the voltage curve changes as the rotor movement continues because the concentration of magnetic lines of force cutting across the loop of wire varies. This occurs because the magnetic field is rather weak at the tips of the poles, and the strongest at the center of the poles.

As the rotor turns from position (2) to position (3), figure 124, the voltage decreases until at position (3) it again becomes zero. It should be noted that from position (1) through (3), the South pole is on top, and the voltage curve above the horizontal line is called positive voltage. This means that the voltage will cause current to flow out the top part of the loop and re-enter the lower part, when the circuit is completed between the ends of the loop of wire.

As the rotor turns from position (3) through (5) in figure]24, the North pole is on top, and the voltage curve is below the horizontal line. The voltage curve is negative, and current will leave the lower part of the loop and re-enter the top when the circuit is completed. Thus, as the top and bottom parts of the loop of wire are influenced alternately by North and South poles, the current flow through the loop of wire flows first in one direction and then in the other. This is alternating current.

Figure 125 portrays the three phase voltages, or voltages between the three winding ends. It is interesting to note that the peak voltage for each phase occurs at equal intervals as the rotor turns. This shows graphically how maximum phase voltage is more nearly constant as described in the previous discussion concerning stator construction.

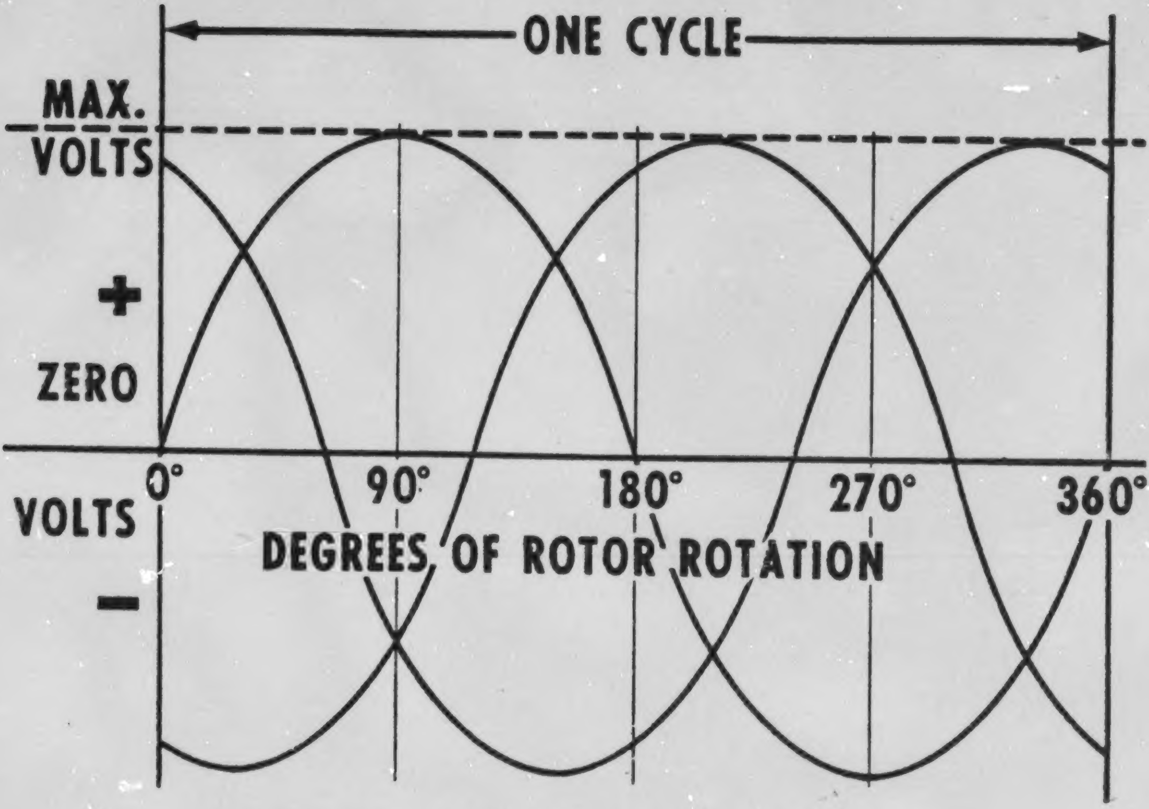


Figure 125. Alternating Voltage (Three Phase).

Rectification

Since the battery and other electrical accessories in the system operate on direct current which flows in only one direction, it is necessary to change the AC current to DC current. This is the job of the rectifying diodes. A diode is an electrical device which allows current to pass freely in one direction, but not in the other. It acts much like an electrical check valve.

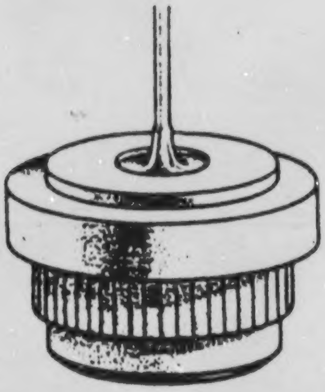


Figure 126. Diode Assembly.

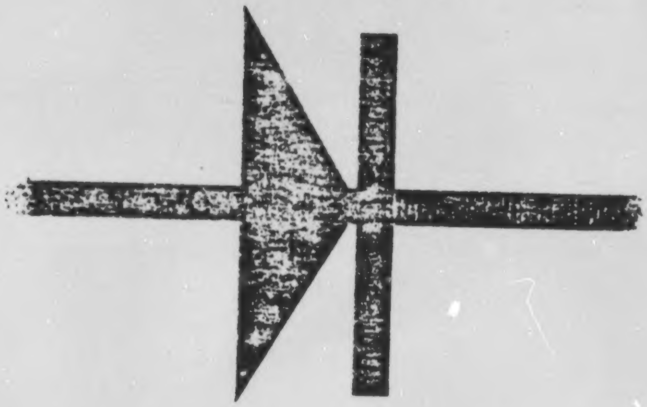


Figure 127. Diode Symbol.

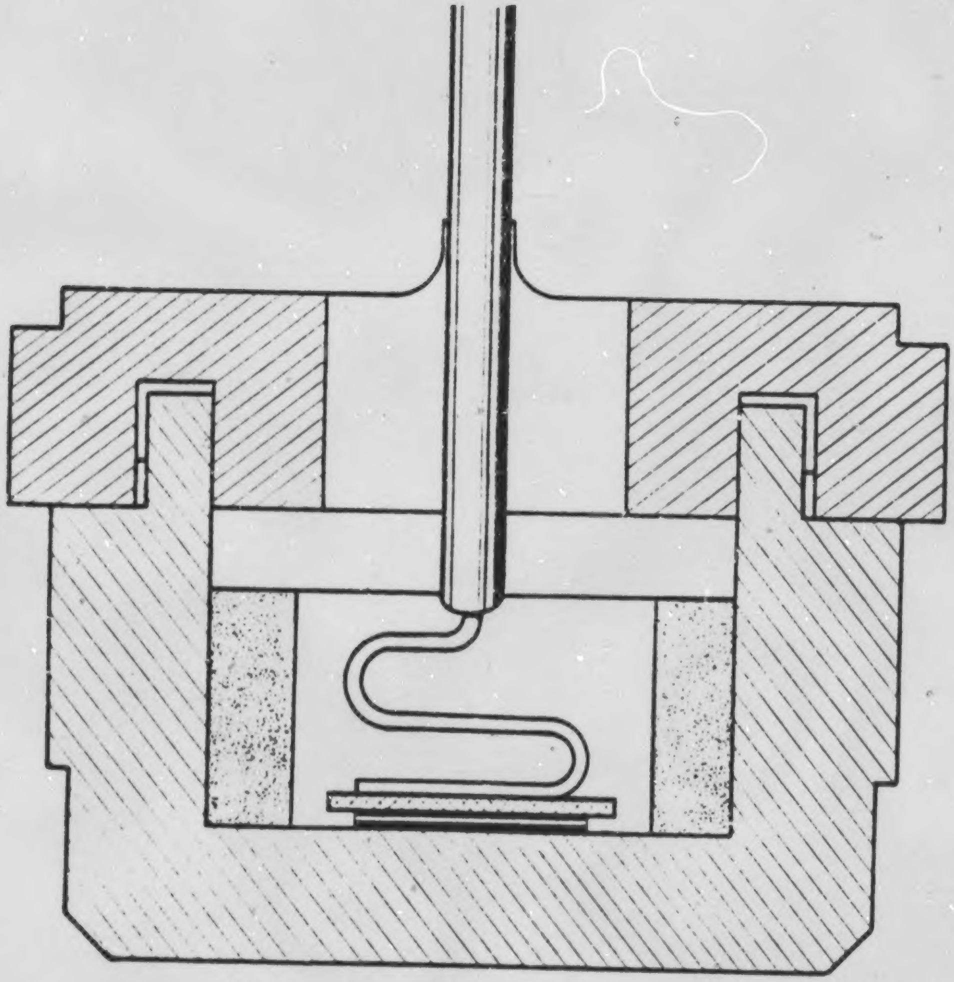


Figure 128. Diode Cross-Section.

An external view of a diode is shown in figure 126. The diode symbol, figure 127, indicates by the arrow that the current will flow only in the direction of the arrow. Any current coming from the opposite direction will be stopped by the bar. A cross sectional view of the diode is shown in figure 128 with a thin silicon wafer, called a "die," in position at the bottom of the diode case. It is the electrical characteristics of the silicon die or wafer which permits current flow in the circuit in only one direction.

> Note: Although the diode is a comparatively rugged component, care should be exercised in handling it. Sudden impacts should be avoided to prevent the possibility of cracking the silicon wafer. If the diode lead is bent excessively, there is the possibility of cracking the glass insulator, permitting moisture to enter the diode. Moisture in the diode could cause it to short and fail to operate. Pulling the diode lead should also be avoided to prevent the possibility of breaking the solder joint between the diode lead and the silicon die. Care must again be used when soldering the stator leads to the diodes as excessive heat may damage the diodes also.

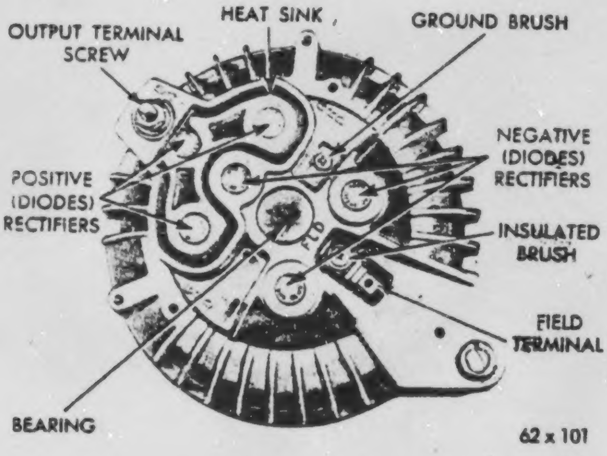

OUTPUT TERMINAL SCREW
HEAT SINK
GROUND BRUSH
NEGATIVE (DIODES) RECTIFIERS
POSITIVE (DIODES) RECTIFIERS
INSULATED BRUSH
FIELD TERMINAL
BEARING
62 x 101

Figure 129A. Rectifier End Frame (Chrysler).

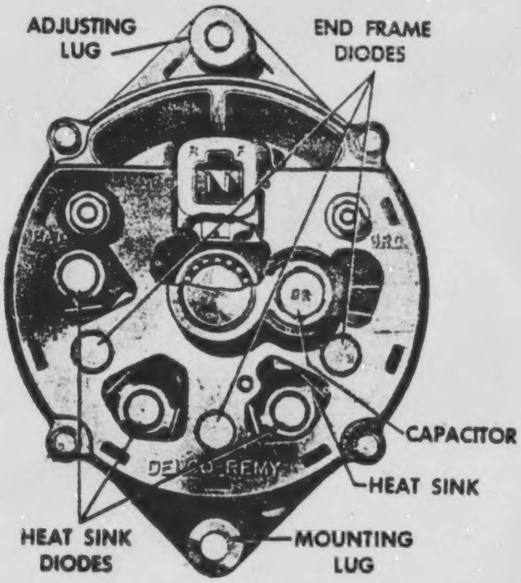

ADJUSTING LUG
END FRAME DIODES
CAPACITOR
HEAT SINK
HEAT SINK DIODES
MOUNTING LUG
DELCO-REMY

Figure 129B. Rectifier End Frame (Delco).

Six diodes are located in the end frame assembly nearest the slip rings. Three of these diodes are negative and all are mounted directly to the end frame, figure 129A. Three positive diodes are mounted into a strip called a "heat sink," figure 129B, which is insulated from the end frame. These diodes change the alternating or AC current which appears at the output or "BAT" terminal of the alternator to direct current for the vehicle's use.

200

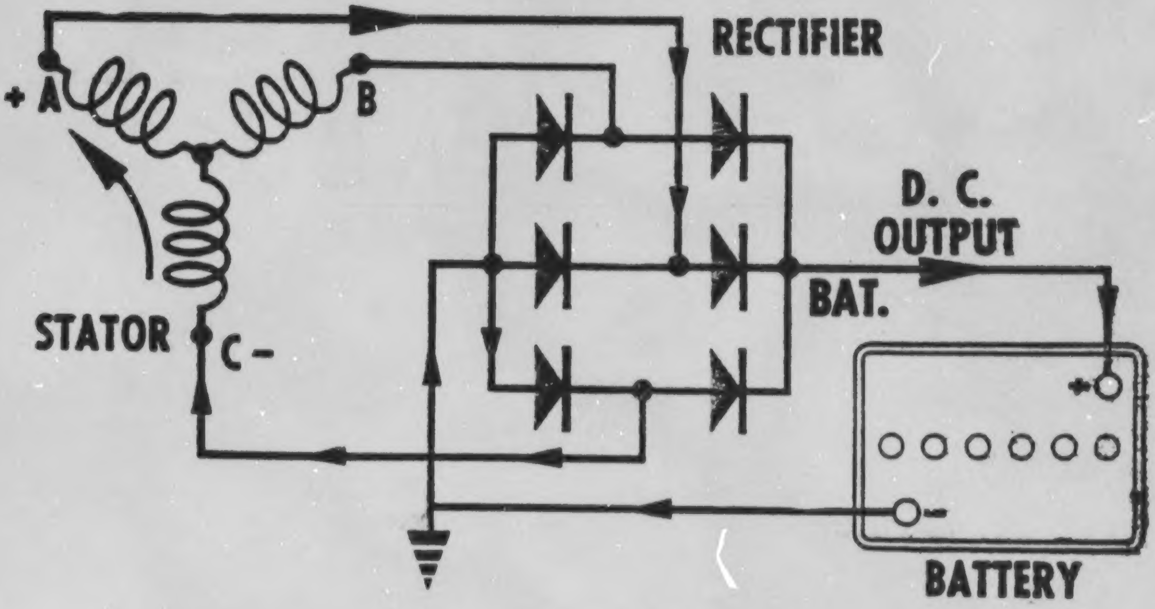


Figure 130. Changing AC to DC.

The method by which the diodes are connected to the stator is shown in figure 130. This type of circuit arrangement provides a smooth flow of direct current to the battery and other accessories connected to the alternator. Also, the blocking action of the diodes prevents battery discharge through the alternator. This eliminates the need for a cutout relay unit.

The condenser connected between the "BAT" terminal of the alternator and ground, figure 130, protects the diodes from voltage surges as they block current flow.

The Importance of Battery Polarity

Let us consider what effect reverse polarity would have and what would happen to output if a diode should become open or shorted. A short circuit through the diodes is created if a battery is installed and connected backwards in the vehicle. Current can flow from the positive terminal of the battery, through the negative and positive diodes in the heat sink. From the heat sink, a completed circuit exists back to the negative battery terminal. Full battery voltage will be impressed or applied on the diodes. The resulting high current will damage the diodes and the wiring harness.

EFFECTS OF AN OPEN DIODE. An opened diode will not allow current to flow in either direction. An open diode upsets the limiting effect of the inductive reactance which normally opposes current flow. This, in turn, results in loss of current control at high rotor speeds. The effect at low speeds is an output that is slightly less than normal.

218

201

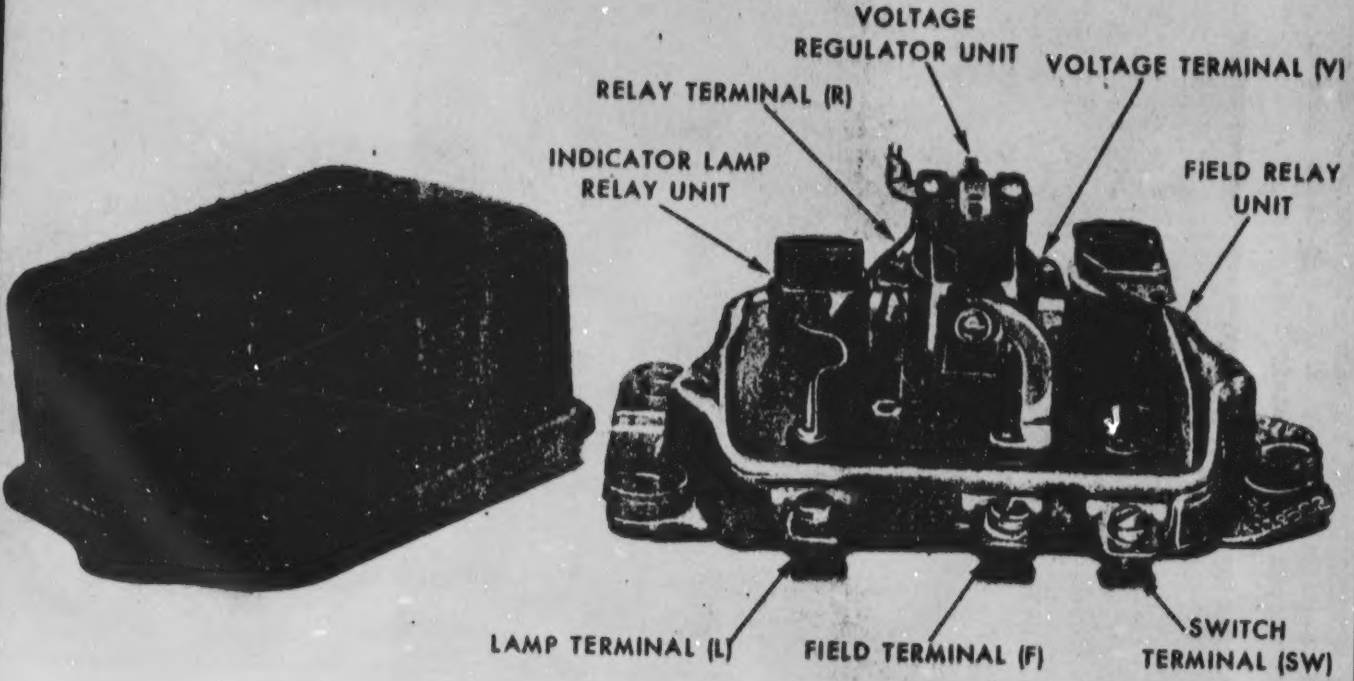

VOLTAGE REGULATOR UNIT
RELAY TERMINAL (R)
VOLTAGE TERMINAL (V)
INDICATOR LAMP RELAY UNIT
FIELD RELAY UNIT
LAMP TERMINAL (L)
FIELD TERMINAL (F)
SWITCH TERMINAL (SW)

Figure 131. Three Unit AC Regulator.

202

EFFECTS OF A SHORTED DIODE. A shorted diode will allow current to flow in both directions. A shorted diode reduces alternator current output approximately 50%.

VIBRATING CONTACT TYPE REGULATORS

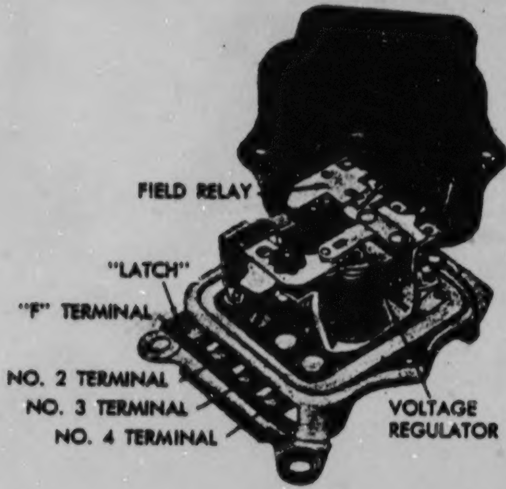

FIELD RELAY
"LATCH"
"F" TERMINAL
NO. 2 TERMINAL
NO. 3 TERMINAL
NO. 4 TERMINAL
VOLTAGE REGULATOR

Figure 132. Two-Unit Regulator.

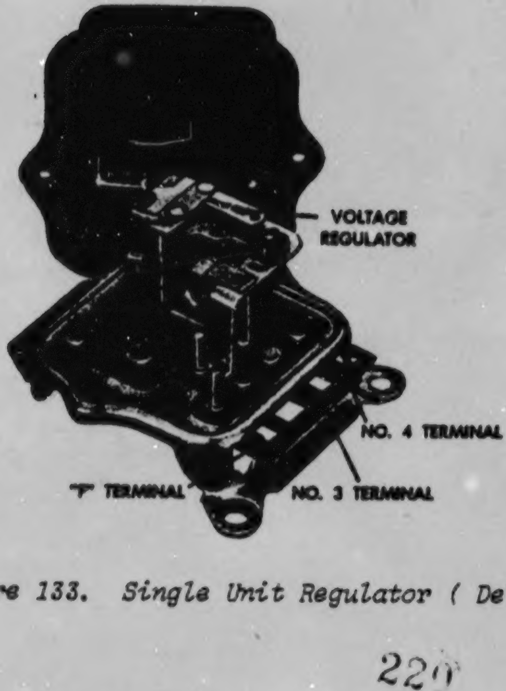

VOLTAGE REGULATOR
NO. 4 TERMINAL
"F" TERMINAL
NO. 3 TERMINAL

Figure 133. Single Unit Regulator (Delco).

220

At the present time, the majority of the alternators are controlled by one of three types of double-contact voltage regulators: A three-unit regulator, figure 131; a two-unit regulator, figure 132; or a single-unit regulator, figure 133. These regulator assemblies do not contain cutout relays or current regulators.

The Single Unit Regulator

This regulator contains a double-contact voltage regulator and is used only for charging systems with an ammeter. A special ignition switch is used to energize the field circuit. The purpose of the voltage regulator is to limit the electrical pressure or voltage developed by the alternator. It protects the battery and the electrical accessories from too high a voltage.

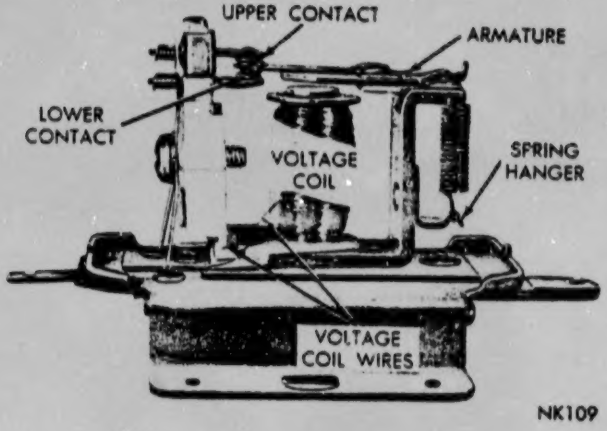

UPPER CONTACT
ARMATURE
LOWER CONTACT
VOLTAGE COIL
SPRING HANGER
VOLTAGE COIL WIRES
NK109

Figure 134. Voltage Regulator (Cover Removed) (Chrysler).

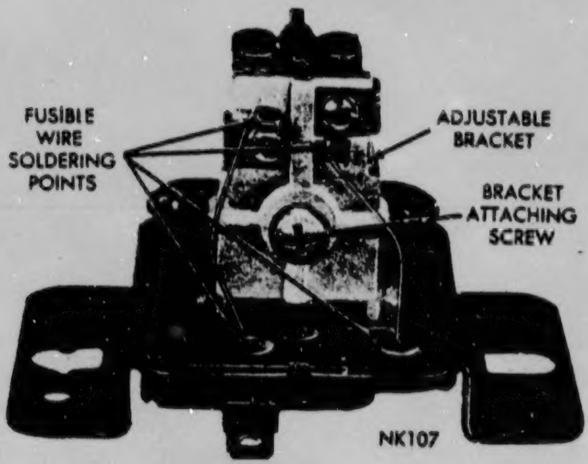

FUSIBLE WIRE SOLDERING POINTS
ADJUSTABLE BRACKET
BRACKET ATTACHING SCREW
NK107

Figure 135. Voltage Regulator Fusible Wires.

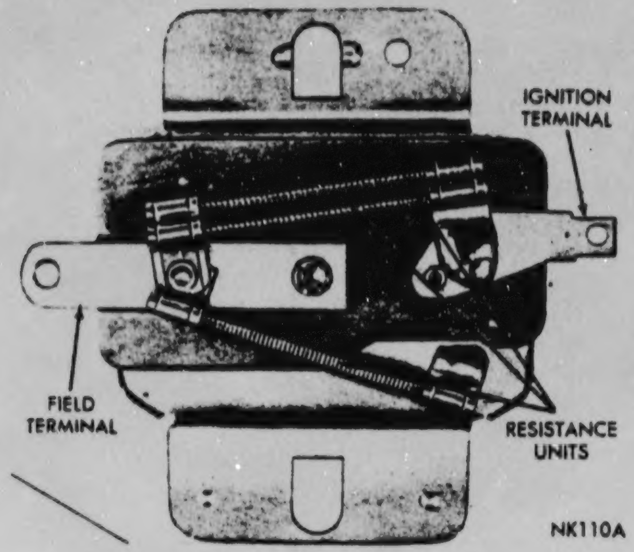


Figure 136. Voltage Regulator Resistance Units.

The voltage regulator, figure 134, has two sets of contacts using a common single armature. The upper and lower stationary contact brackets are mounted on a molded plastic bracket which is attached to the regulator frame by a screw. The upper contact bracket is connected to the IGN (ignition) terminal by a fusible wire, figure 135. The lower contact bracket is connected to ground by another fusible wire. The armature is connected to the insulated FLD (field) terminal. Three resistors are used, shown in figure 136. Two control resistors are connected in parallel with the upper set of contacts between the IGN and FLD terminals. One bleeder resistor is connected between the IGN terminal and ground. The bleeder resistor's function is to reduce arcing at the regulator contacts.

Operation of the regulator will be explained by illustrating the current flow through the regulator. The following explanations refer to the Chrysler built regulator. Other regulators are basically the same.

MOVEABLE CONTACT CLOSED AGAINST UPPER CONTACT POINT. Figure 137 illustrates current flowing from the ignition terminal of the regulator, through the upper stationary point, through the moveable point, continuing through the rotor field coil and then to ground. Since resistance in this circuit is low, maximum current will flow through the rotor field coil. Rotor field strength will be high. Alternator output will be at its maximum for any given rotor speed. Current flow through resistors (1) and (2), as well as number (3), is negligible when the field circuit through the upper contacts is completed.

MOVEABLE CONTACT POINT VIBRATING AGAINST UPPER CONTACT POINT. When the engine is operating at moderate speed and the electrical load on the alternator is low, the voltage will rise.

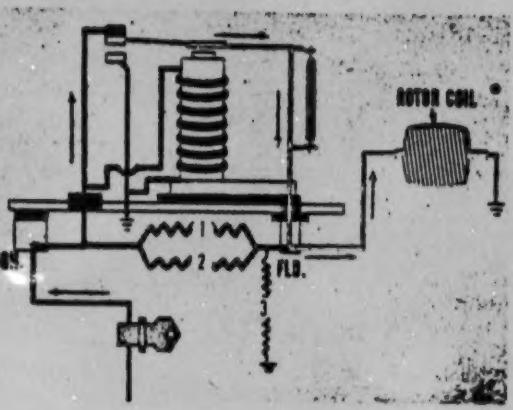


Figure 137. Voltage Regulator Circuits - Upper Contacts Closed.

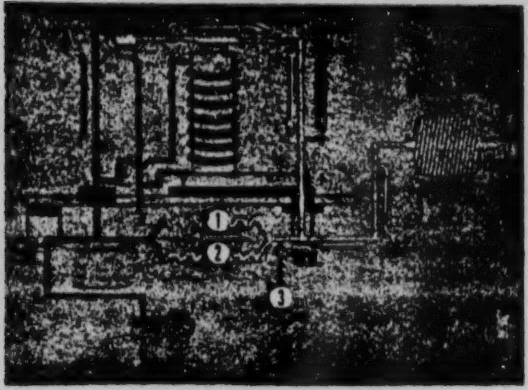


Figure 138. Movable Contact Vibrating Against Upper Contact.

At this time the regulator points will vibrate. This action of the points will reduce current flow to the field windings (rotor coil) varying the strength of the magnetic field as necessary to keep voltage from rising over a specified setting. When the points are closed, maximum current will flow to the field winding; when the points are separated, the current must flow between resistors (1) and (2), figure 138, which reduces the current flow to the field winding and weakens the strength of the magnetic field.

MOVEABLE CONTACT POINT OPERATING IN "FLOAT" OR "BALANCED" POSITION. Whenever a condition exists where load, speed, and battery demands for current are equal, the points will be in the "float" or "balanced" position. With the points in the float position, the current flows only through resistors (1)

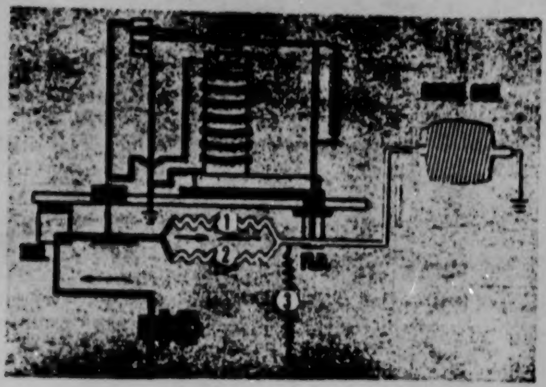


Figure 139. Movable Contact Operating in "Float."

and (2), figure 139, which reduces current flowing to the field winding somewhat lower than when the moveable contact point was vibrating against the upper contact point. This maintains a weaker field in the rotor coil and limits alternator voltage more than before.

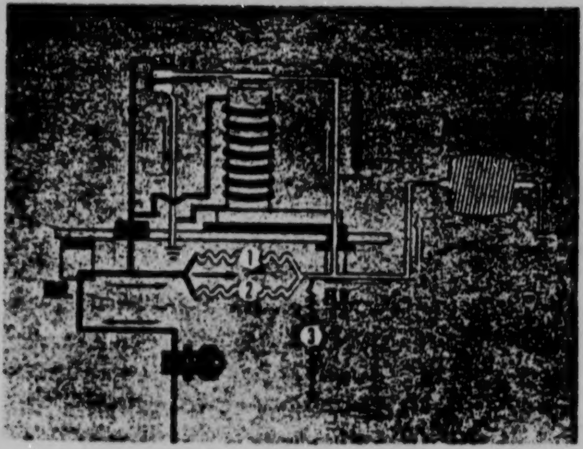


Figure 140. Movable Contact Vibrating Against the Lower Contact.

MOVEABLE CONTACT POINT VIBRATING AGAINST LOWER CONTACT POINT. With the engine operating at high speed and the alternator at low current output, the alternator voltage will rise, even with a weak magnetic field in the rotor field coil. The rising voltage will pull the moveable contact point down on the lower contact point, which is grounded, figure 140. This action will not allow current to flow in the field in the coil to a minimum, preventing excessive voltage rise.

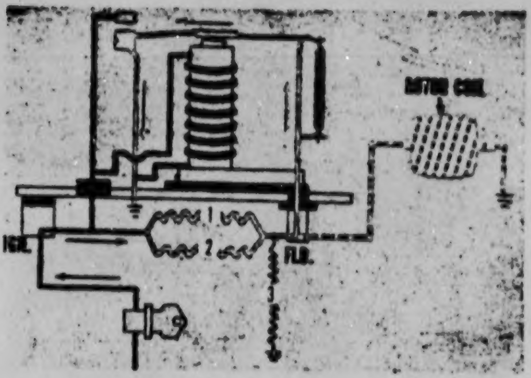


Figure 141. Voltage Regulator Circuits - Lower Contact Closed.

MOVEABLE CONTACT POINT CLOSED AGAINST LOWER CONTACT POINT. When electrical load demand is low and engine speed is high, the alternator voltage tries to increase beyond safe limits. However, the increased voltage acting on the voltage coil causes the moveable contact to close on the lower contact. Current flow is through resistors (1) and (2) to the field terminal of the regulator. Resistance through the regulator armature to the moveable contact and thence through the lower contact to ground, figure 141, is much lower than the resistance of the rotor coil. The alternator field circuit is momentarily bypassed, dropping alternator output when the lower contact circuit is completed.

The Two-Unit Regulator

A double contact voltage regulator unit and a field relay unit are contained in the two-unit regulator, figure 142. It is used in charging systems having either an indicator lamp ("idiot light") or an ammeter. However, the external wiring, on various applications, may differ.

THE VOLTAGE REGULATOR UNIT. The operation of the voltage regulator unit, figure 142, in the two-unit regulator is the same as described in the single unit regulator.

THE FIELD RELAY UNIT. The field relay unit, figure 142, which is the second unit in the regulator, is a simple magnetic switch which energizes the field coil by connecting it to the battery when the ignition switch is closed. When the ignition switch is opened, the field relay contacts separate to disconnect the field coil from the battery. This prevents the battery from discharging through the rotor field coil when the engine is stopped. The field relay unit of the two-unit regulator may also act as an indicator lamp relay on many applications.

The Three-Unit Regulator

This regulator, figure 143, contains a double-contact type voltage regulator unit, a field relay unit, and an indicator lamp relay unit. It is used in charging systems using either an indicator lamp or an ammeter. It is not interchangeable with the two-unit regulator.

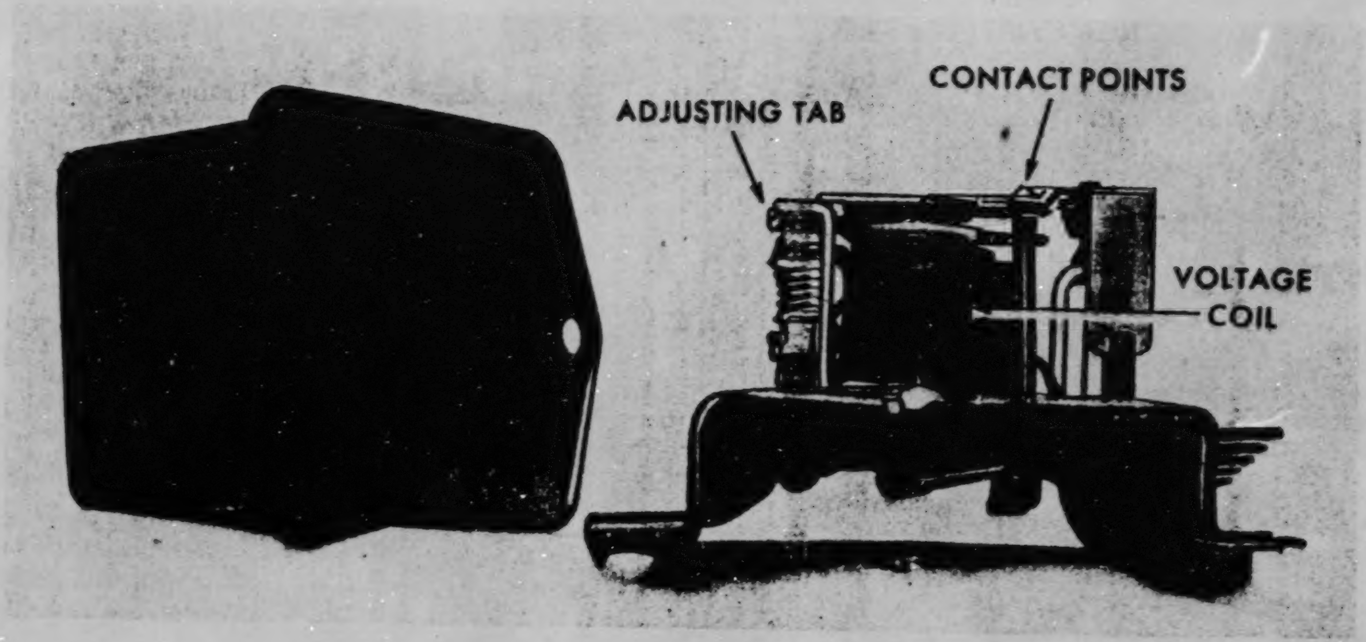

CONTACT POINTS
ADJUSTING TAB
VOLTAGE
COIL

Figure 142. Field Relay Unit of Two Unit AC Regulator.

2

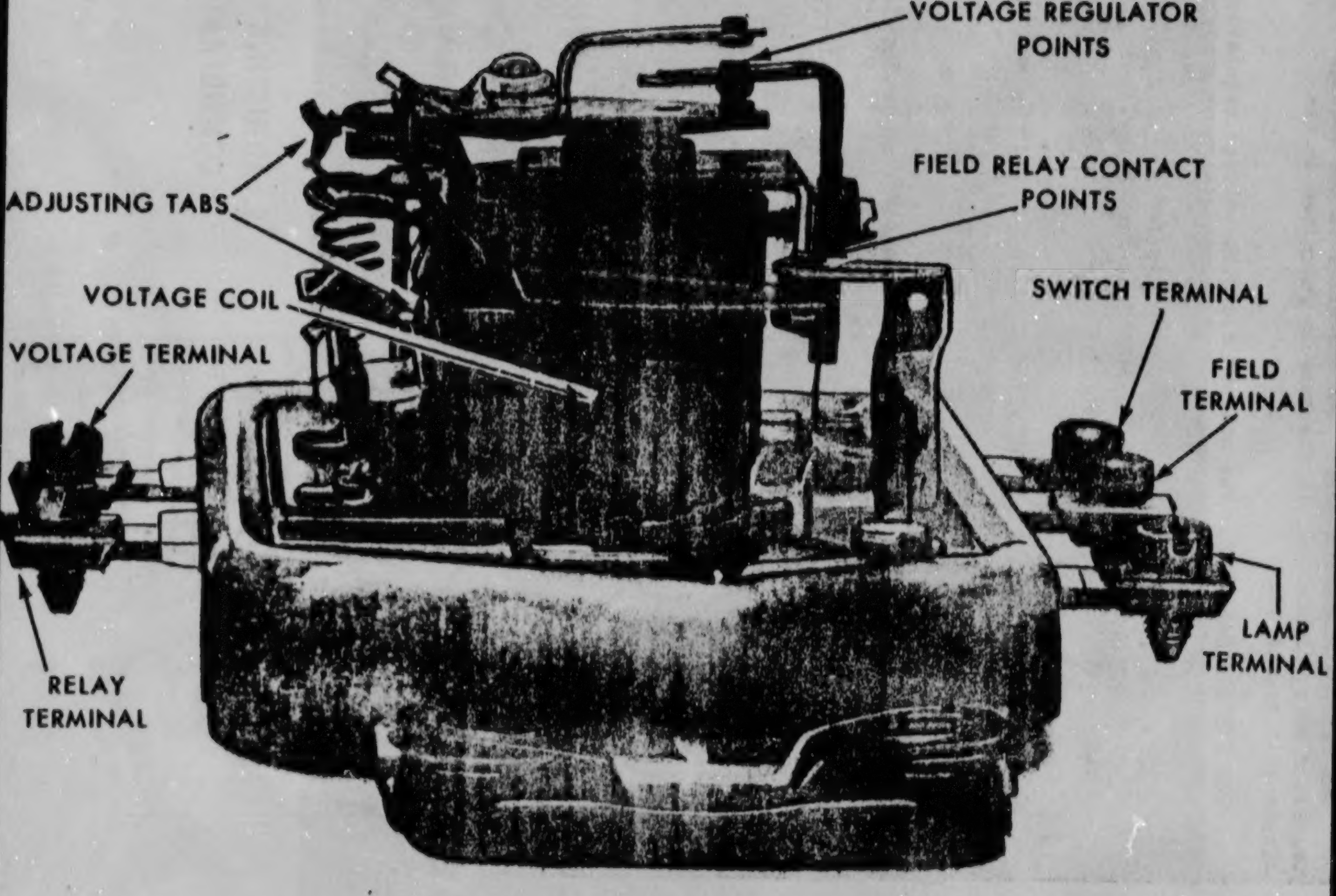

VOLTAGE REGULATOR POINTS
ADJUSTING TABS
FIELD RELAY CONTACT POINTS
VOLTAGE COIL
SWITCH TERMINAL
VOLTAGE TERMINAL
FIELD TERMINAL
LAMP TERMINAL
RELAY TERMINAL

Figure 143. Indicator Lamp Relay Unit.

THE VOLTAGE REGULATOR UNIT. The operation of the voltage regulator unit, figure 143, is the same as described in the single unit regulator.

THE FIELD RELAY UNIT. The operation of the voltage regulator unit, figure 143, is the same as described in the single unit regulator.

THE FIELD RELAY UNIT. The operation of the field relay unit, figure 143, is the same as previously described in the two-unit regulator.

THE INDICATOR LAMP RELAY UNIT, FIGURE 143. The wiring of charging systems using an indicator lamp relay is such that the indicator lamp "lights" when the ignition switch is first turned on. Then, when the alternator develops voltage and begins to furnish power, the indicator lamp goes "out." This indicates that the charging system is operating normally. If the alternator fails to furnish power at any time, the indicator lamp comes "on", indicating there is trouble in the charging system.

TRANSISTOR REGULATORS

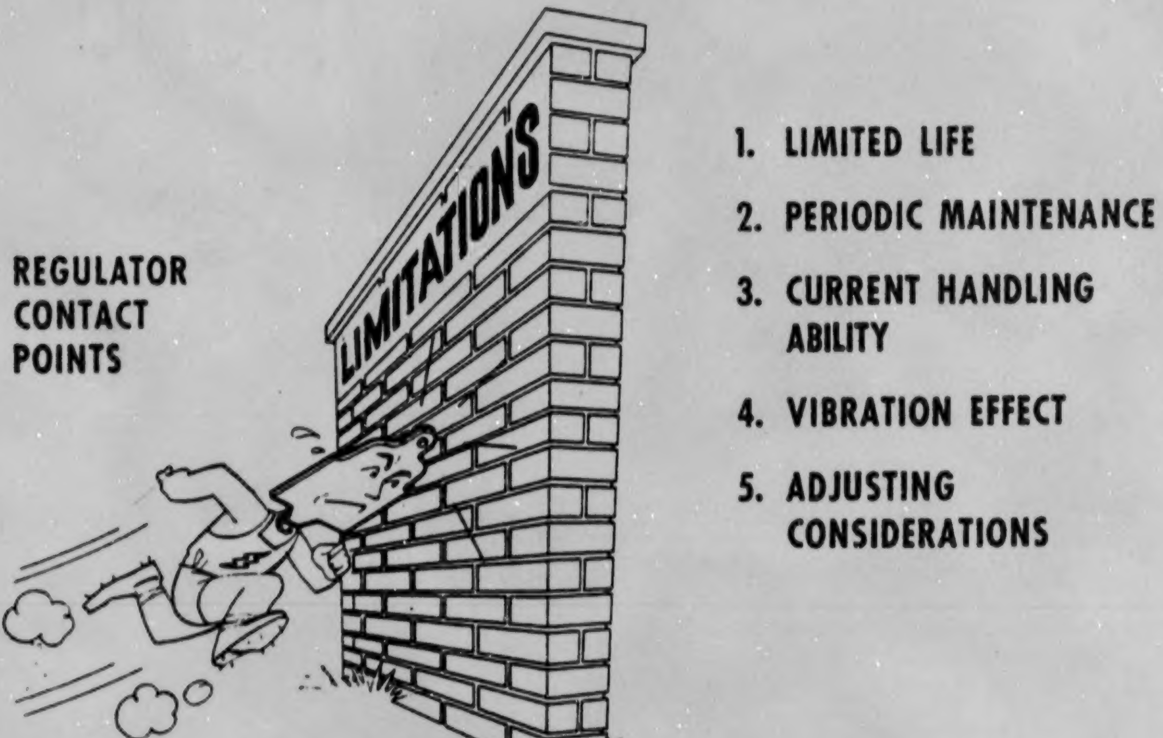

LIMITATIONS
REGULATOR
CONTACT
POINTS
1. LIMITED LIFE
2. PERIODIC MAINTENANCE
3. CURRENT HANDLING ABILITY
4. VIBRATION EFFECT
5. ADJUSTING CONSIDERATIONS

Figure 144. Regulator Contact Point Limitations.

The design and performance of the entire charging system is restricted because of certain limitations of the contact points located in the regulator, figure 144. The disadvantages of the contact points are limited life, periodic maintenance, current handling limitations, vibration effect and adjusting considerations. To improve the operation of the existing systems and to keep pace with electrical demands, new regulators were designed. These voltage regulators replaced the conventional contact points with transistors.

Transistors

Transistors are electrical devices which act as electrical switches. They can be turned "on" or "off" to control a circuit. A transistor has no moving parts. Its operation is entirely electronic. There appears to be no limit to its lifetime provided it is used for the purpose for which it was designed. The transistor, therefore, is a good replacement for contact points. Better output, increased efficiency, more reliable and longer life systems, and fewer or no servicing requirements are features of the transistor which offer great improvements to the electrical system.

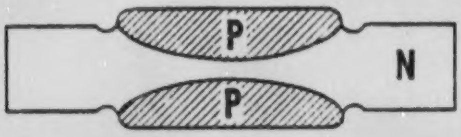


Figure 145. Transistor Material.

CONSTRUCTION OF THE TRANSISTOR. For a simple understanding of the transistor, it is best to consider it as an electronic device that has very definite characteristics. Figure 145 portrays the materials that make up the transistor. Note that there are two pieces of "P" material and one piece of "N" material. The manner in which these materials will react when connected in an electrical circuit can be predicted.

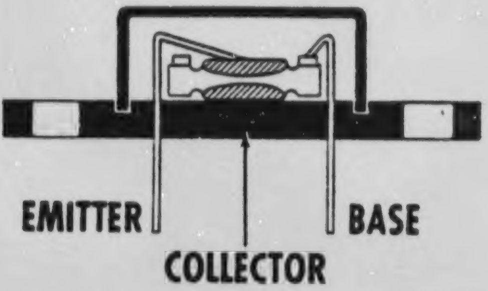


Figure 146. Transistor Construction.

Figure 146 shows the construction of the transistor. A lead is connected to each of the three materials, called emitter, base, and collector. Note that the collector is the mounting pad of the transistor.

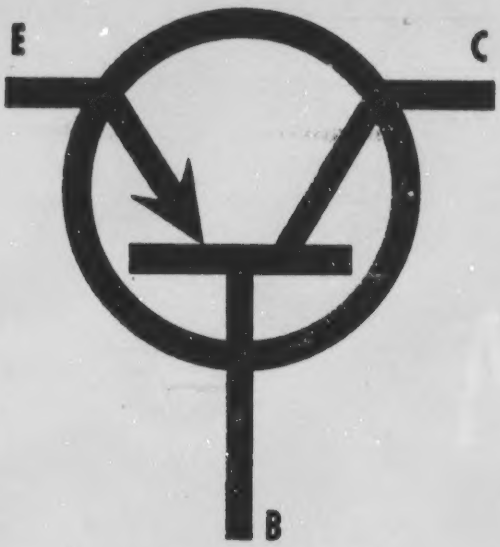


Figure 147. Transistor Symbol.

The transistor symbol used in wiring diagrams is shown in figure 147. Note that there are only three connections. The arrow always points in the direction of current flow in automotive manuals using this symbol.

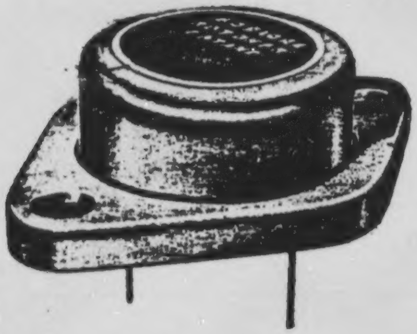
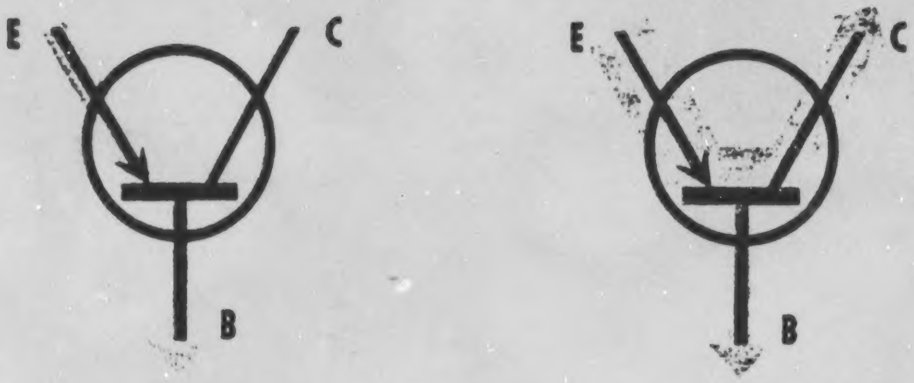


Figure 148. Transistor Appearance.

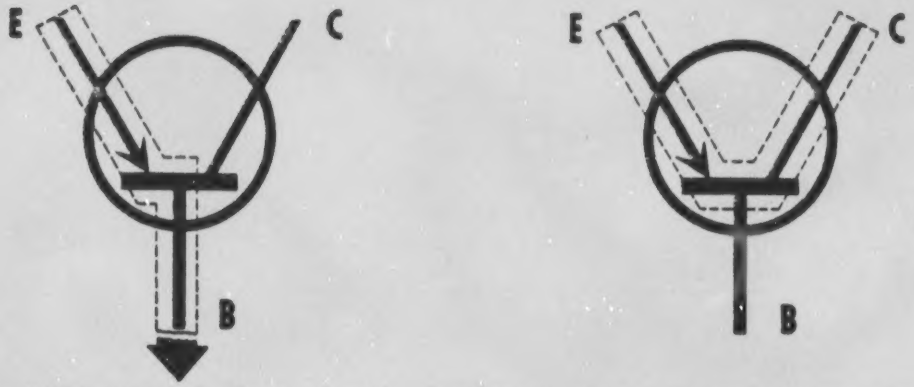
Figure 148 shows the actual appearance of the transistor. Many different types and sizes of transistors are manufactured. The one shown is the type used in automotive electrical systems.

OPERATION OF A TRANSISTOR. Figure 149 shows a transistor and indicates the manner in which it operates. Only when there is current flow in the emitter-base circuit, is there current flow in the emitter-collector circuit. The emitter-base circuit requires only a small current. Therefore it acts as a trigger to turn this electronic switch on in the emitter-collector circuit. The small current in the emitter-base circuit controls a much larger current flow in the emitter-collector. If there is no current flow in the emitter base circuit, then there is no current flow in the emitter-collector circuit. The emitter-base circuit can also act as a trigger to turn the emitter-collector circuit off.



IF THIS • THEN • THIS

WITH VERY LITTLE CURRENT FLOW IN THE EMITTER-BASE CIRCUIT, A GREATER CURRENT CAN BE ESTABLISHED IN THE EMITTER-COLLECTOR CIRCUIT.



IF NO CURRENT FLOW HERE • THEN • NO CURRENT FLOW HERE

WITH NO CURRENT FLOW IN THE EMITTER-BASE CIRCUIT, THERE IS NO CURRENT FLOW IN THE EMITTER-COLLECTOR CIRCUIT.

Figure 149. Transistor Operation.

If the emitter-base circuit of the transistor can be manipulated either on or off, then the greater current carrying emitter-collector circuit can also be made to operate either on or off at the same time. The emitter-collector circuit, therefore, is used in place of a set of contact points. The emitter-base circuit is the means by which the emitter-collector circuit is controlled.

Operation of the Transistor Regulator

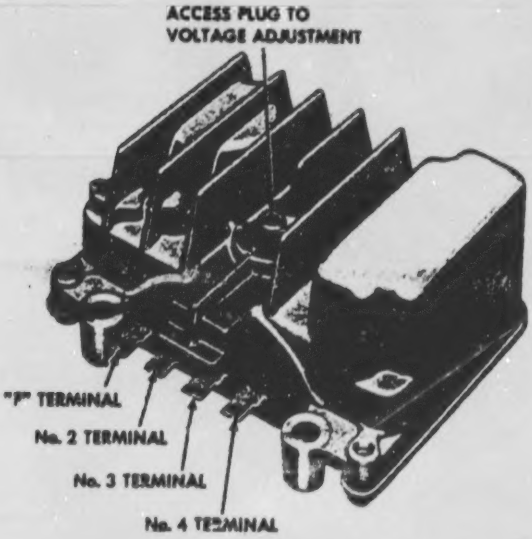


Figure 150. Transistor Regulator.

A typical transistor regulator is shown in figure 150. A simplified wiring diagram showing the circuit of this transistor regulator is illustrated in figure 151. When the ignition switch is closed, battery voltage supplies current through the emitter-collector of the transistor to the field coil of the alternator. This circuit is complete since the transistor is turned "on" by a higher voltage on the emitter than on the base, which permits emitter-base current to flow. The flow of the field current to the field circuit of the alternator provides the magnetic field for the alternator. When the engine is started, the alternator builds up in voltage. This causes current to flow to charge the battery and power the accessories.

As alternator speed increases, its voltage builds up to a predetermined value. Then the electrical control portion of the regulator places a higher voltage on the base of the transistor than that on the emitter. The transistor is turned "off". With no current flow in the emitter-collector, there is no current flow in the field coil of the alternator. As a result, alternator voltage falls to a predetermined value. Then the electrical control portion of the regulator places a lower voltage on the base of the transistor than that on the emitter. The transistor is turned "on". Current again flows through the emitter-collector and the field circuit. The magnetic field is built up in the

215

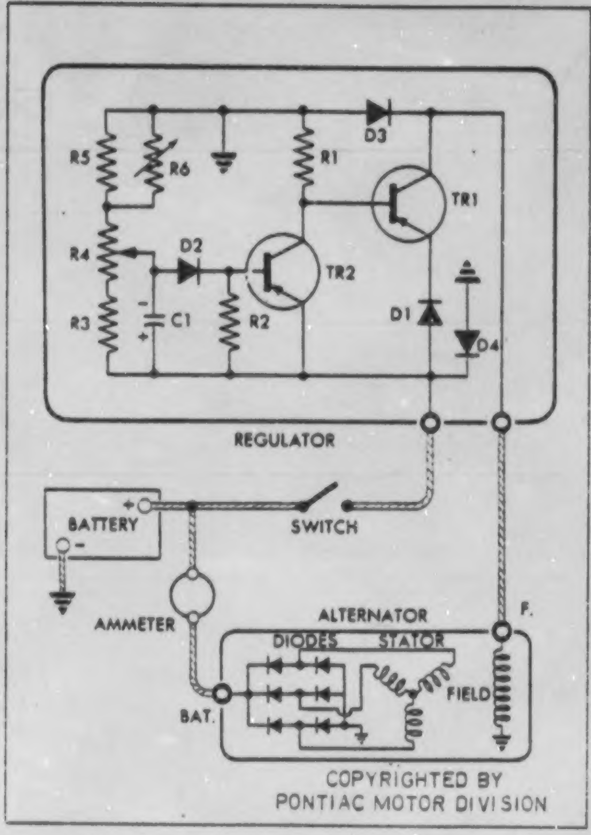

R5
R6
R1
D3
TR1
R4
D2
TR2
R3
C1
R2
D1
D4
REGULATOR
BATTERY
SWITCH
AMMETER
ALTERNATOR
F.
DIODES
STATOR
FIELD
BAT.
COPYRIGHTED BY
PONTIAC MOTOR DIVISION

Figure 151. Regulator in Charging Circuit.

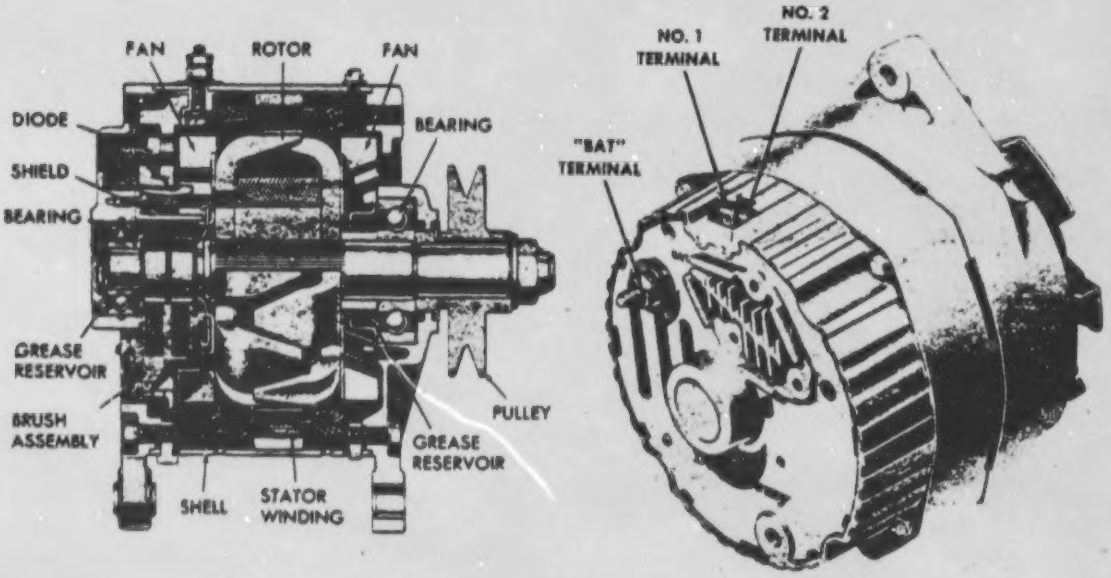

FAN
ROTOR
FAN
DIODE
BEARING
SHIELD
BEARING
GREASE RESERVOIR
BRUSH ASSEMBLY
PULLEY
GREASE RESERVOIR
SHELL
STATOR WINDING
NO. 1 TERMINAL
NO. 2 TERMINAL
"BAT" TERMINAL

Figure 152. 10-S1 Series Type 100 Delcotron With Integral Regulator.

alternator again and voltage rises. The "on" and "off" switching action of the transistor acts to regulate the field circuit of the alternator to limit alternator voltage at a safe value.

Integral Regulator

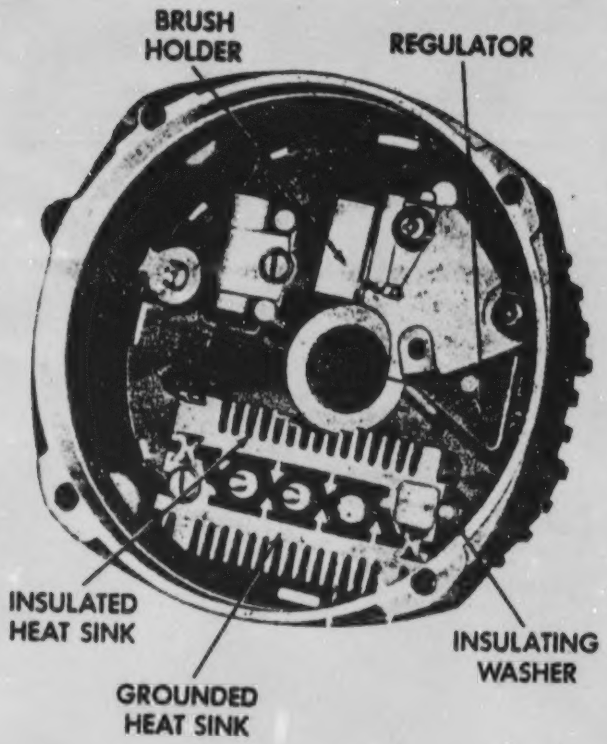


Figure 153. Interior View of Delcotron With Integral Regulator.

Beginning in 1968, Delco-Remy began producing a self-contained charging system with miniaturized integrated circuits which eliminates the traditional voltage regulator. This unit is shown in figure 152. The system voltage is controlled by an integral regulator within the alternator, figure 153. In other words, there is no separate regulator mounting, no external wiring between regulator and alternator, no voltage adjustments for the life of the unit, and no periodic maintenance.

MAINTENANCE AND SERVICING

Alternator Servicing

Now that we have seen how the alternator and the AC charging system is constructed and how it operates, let's look at a few service procedures. The following information is general in nature, so reference always should be made to the manufacturer's maintenance manual for the correct service procedures.

BEARINGS. The alternator rotor is supported by a ball bearing at the drive end and a roller bearing at the rectifier end. Each bearing has a lubricant supply which eliminates the need for periodic lubrication. However, after periods of extended operation or at engine overhaul time, the bearings should be checked to see that they are in satisfactory condition. Hold the alternator pulley with fingers and note the side play and freeness of rotation to determine the condition of the bearings. If the bearings are rough, worn, or have excessive side play, they should be replaced.

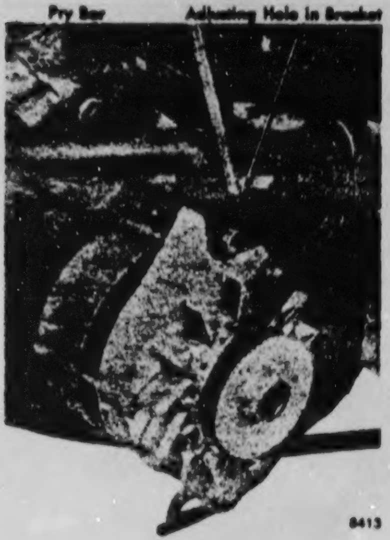


Figure 154. Adjusting Belt Tension.

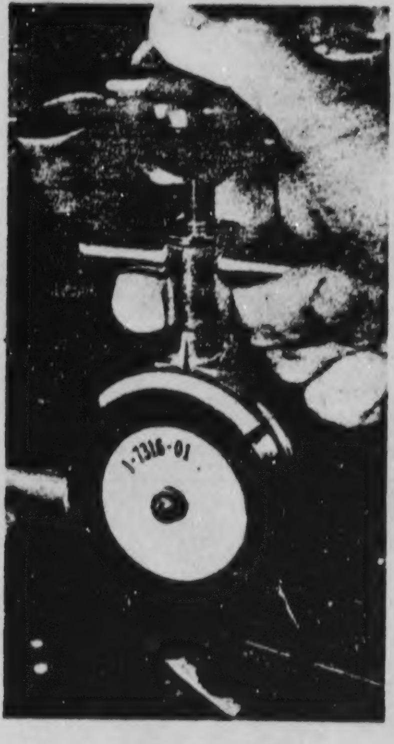


Figure 155. Checking Belt Tension With Gauge J-7316.

FAN BELT. Periodically the fan belt should be examined for wear or glazing from slipping and bottoming in the pulley. Replace the belt if necessary. If two belts are used, both must be replaced

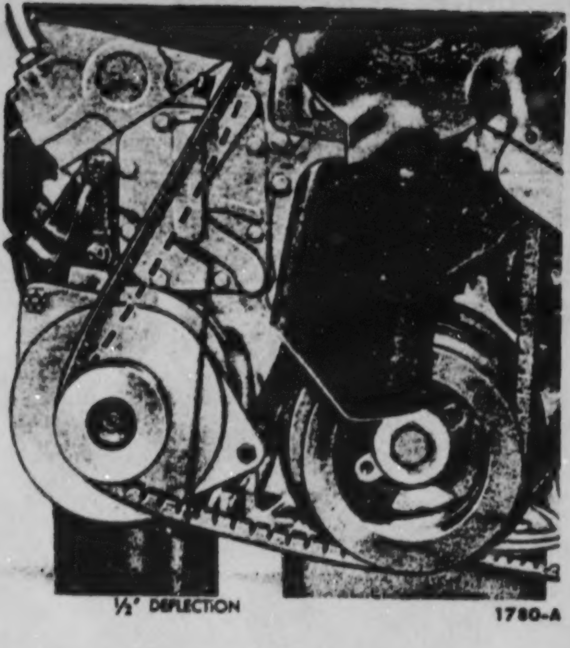

½" DEFLECTION
1780-A

Figure 156. Fan Belt Deflection - Typical.

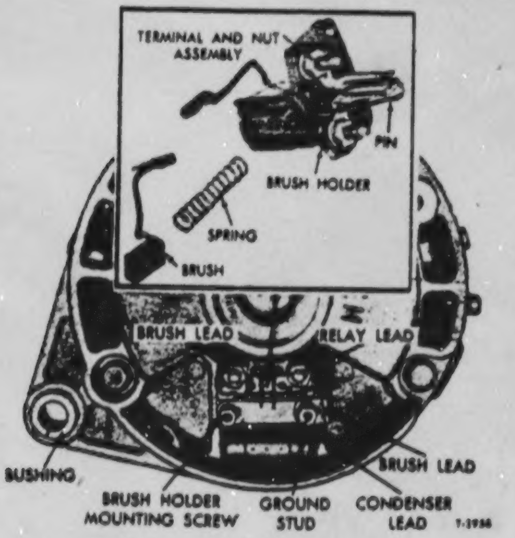

TERMINAL AND NUT ASSEMBLY
PIN
BRUSH HOLDER
SPRING
BRUSH
BRUSH LEAD
RELAY LEAD
BRUSH LEAD
BUSHING
BRUSH HOLDER MOUNTING SCREW
GROUND STUD
CONDENSER LEAD
1-1936

Figure 157. Delcotron Brush Holder Assembly.

at the same time. Loose or slipping belts are quite often the cause of a run-down battery. Additionally, loose belts can cause excessive heat and bearing failure will be the result. Tighten the belt per vehicle manufacturer's specifications, if necessary, figure 154. Do not overtighten the belt as this will put an undue strain on the bearings and cause premature bearing failure. A belt tension gage, figure 155, should be used to measure proper belt tension. Another method used to check belt tension is to note how much the belt can be deflected by pressing on it, figure 156, and comparing to manufacturer's specifications.

BRUSHES. The two alternator brushes are used to carry current through the two slip rings to the field coil which is mounted on the rotor. The brushes are extra long and under normal operating conditions will provide long periods of service. No periodic servicing, therefore, is required for the brushes. However, after periods of extended service or at engine overhaul time, the brushes should be checked to insure that they are in satisfactory condition. If the brushes are worn halfway, they should be replaced. Also inspect brush springs for distortion or weakening. In some applications, brushes, springs, and brush holders are replaced as a unit. See figure 157.

ROTOR ASSEMBLY. The rotor windings may be checked for grounds by connecting a test lamp from either slip ring to the shaft. A test lamp will light if the rotor winding is grounded. To check the rotor windings for opens, shorts, and resistance, connect an ammeter in series between the rotor and a battery. An ammeter reading above the specified field current draw indicates a short, whereas a reading below the specified value indicates resistance. No reading at all would indicate an open in the rotor windings.

STATOR ASSEMBLY. The stator windings may be checked for opens after it has been disconnected from the end frame. If a test lamp lights when connected between each pair of stator leads, the stator winding is electrically good. If a test lamp does not light when connected from any one of the leads to the stator frame, it indicates the windings are not grounded. It is not practical to check the stator for shorts due to the very low resistance of the windings.

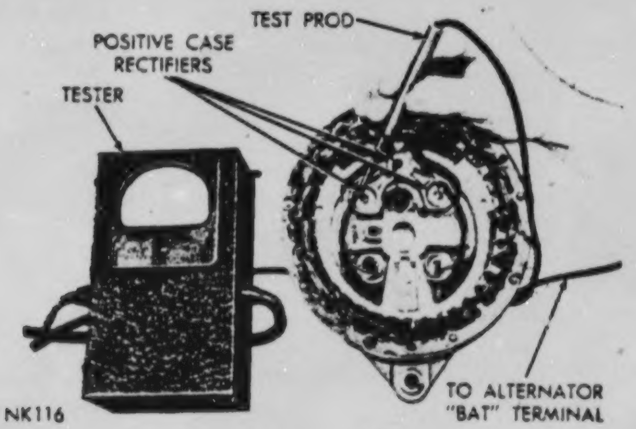


Figure 158. Testing Positive Rectifiers With Diode Tester.

DIODES. The preferred method to check the alternator diodes is to use a special diode tester, as shown in figure 158. No procedure can be given here because of the different types of diode testers available. An alternate method of testing the diodes is to use a test lamp and a 12-volt battery. The diodes must be disconnected from the stator leads if this method is used.

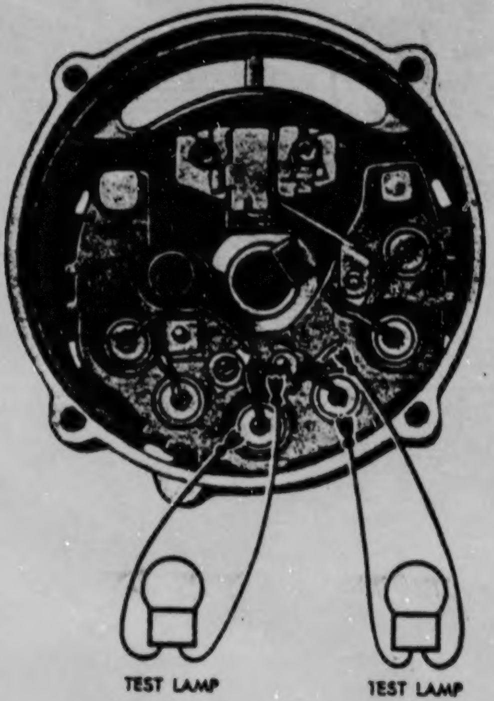


Figure 159. Checking Diodes With Test Lamp.

Connect one of the test leads to the diode lead and the other test lead to the diode case, figure 159. Then reverse the lead connections. If the lamp lights in both directions, the diode is shorted. Also, if the lamp fails to light in both directions, the diode is open. When checking a diode, the lamp will light in only one of the two checks.

Regulator Servicing

The following information is general in nature. Reference should always be made to the manufacturer's manual for correct service.

VIBRATING CONTACT TYPE REGULATOR. Normally no periodic servicing is required for the regulator. However, contact points of the voltage regulator unit that have excessive resistance or a sticking tendency can cause poor regulator performance. This, in turn, affects the performance of the alternator. When this condition exists, the contacts should be cleaned. The contact points should be cleaned with a fine abrasive paper, such as a strip of 400 silicon carbide paper. Never use a file, emery cloth or sandpaper to clean double-contact type voltage regulator contacts.

> Note: A sooty or discolored condition of the contacts is normal after a relatively short period of operation. This is not an indication that cleaning is necessary.

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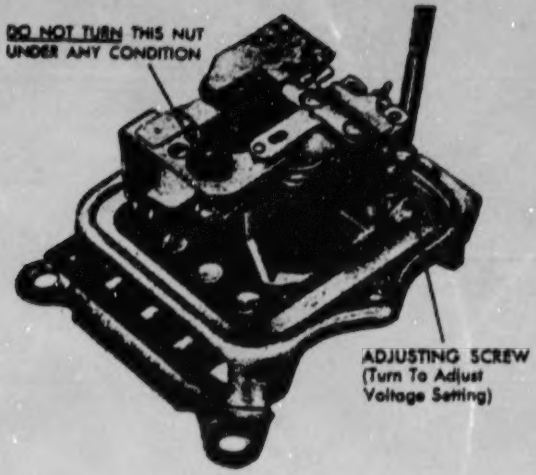
DO NOT TURN THIS NUT
UNDER ANY CONDITION
ADJUSTING SCREW
(Turn To Adjust
Voltage Setting)

Figure 160. Adjusting Voltage Regulator Setting.

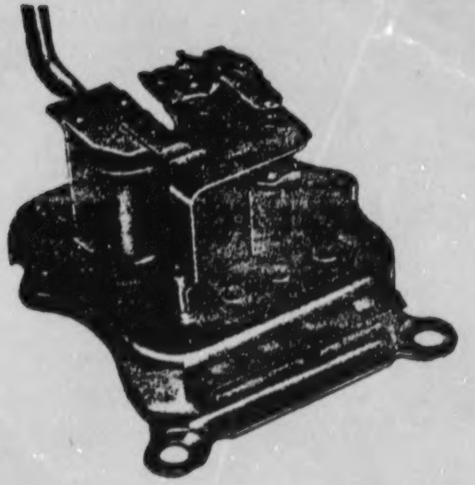

Figure 161. Adjusting Field Relay Closing Voltage.

If it is necessary to adjust the voltage regulator setting, turn the voltage adjusting screw, figure 160, to either increase the setting or decrease the setting of the regulator. The field relay closing voltage is adjusted by bending the heel iron in the manner illustrated in figure 161.

TRANSISTOR REGULATORS. The transistor regulator controls alternator voltage by electronic means. It has no moving parts as employed in the vibrating point type of regulator. Therefore no periodic maintenance or adjustment of the regulator is required.

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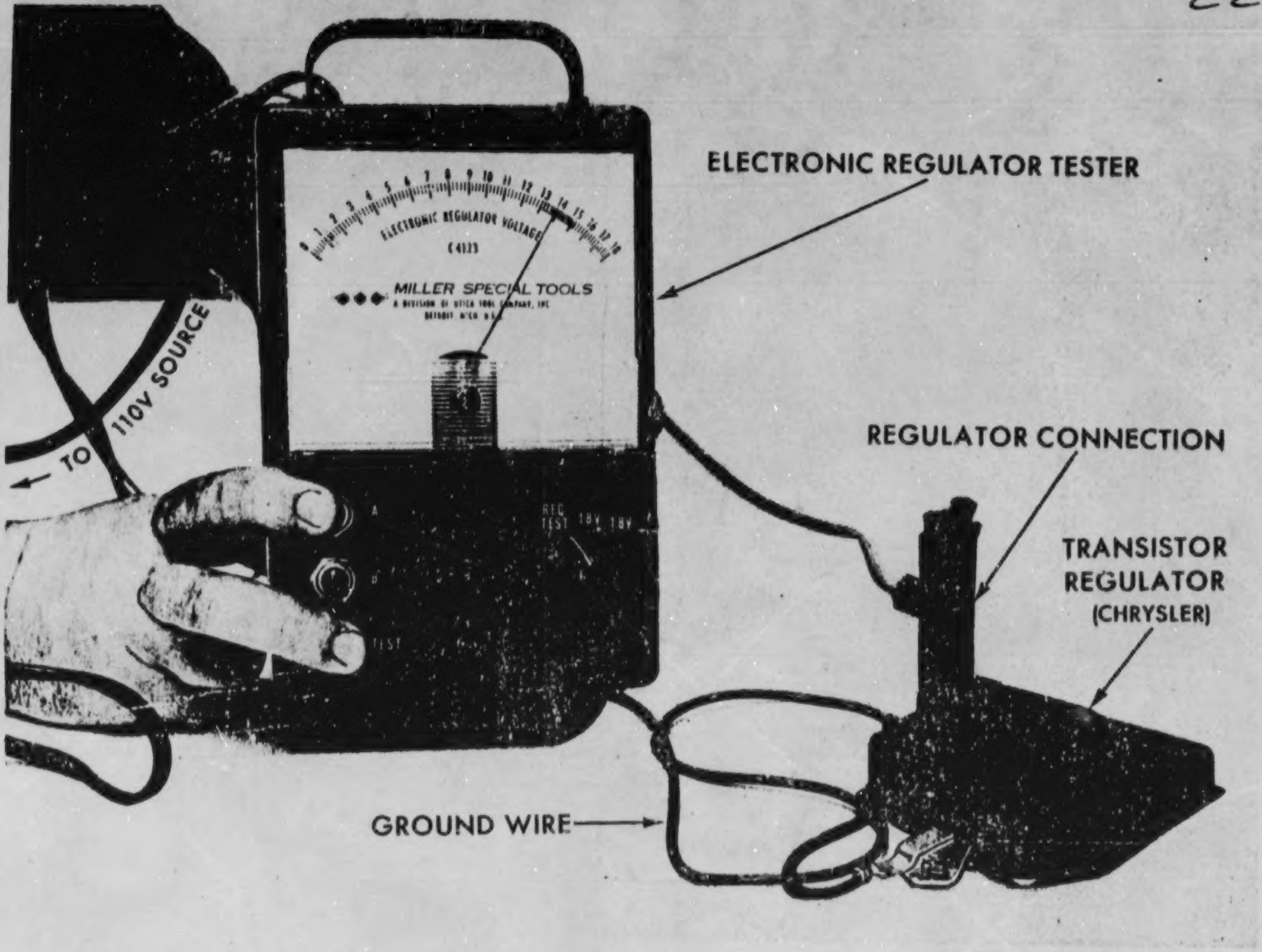
ELECTRONIC REGULATOR TESTER
ELECTRONIC REGULATOR VOLTAGE
MILLER SPECIAL TOOLS
TO 110V SOURCE
REGULATOR CONNECTION
TRANSISTOR
REGULATOR
(CHRYSLER)
A
B
TEST
REG TEST
18V
GROUND WIRE

Figure 162. Testing Transistor Regulator With Electronic Tester.

If the regulator is suspected of malfunctioning, it should be tested with a special electronic voltage regulator tester, figure 162. If the regulator is found to be at fault, it should be replaced.

> Note: On some models of transistor regulators, it is possible to adjust the voltage regulator setting ± 0.6 volt. Remove the pipe plug and insert a screwdriver into the slot. Turn the screwdriver clockwise one or two notches to increase the setting, or one or two notches counterclockwise to decrease the setting, figure 163. For each notch moved, the voltage setting will change approximately 0.3 volt.

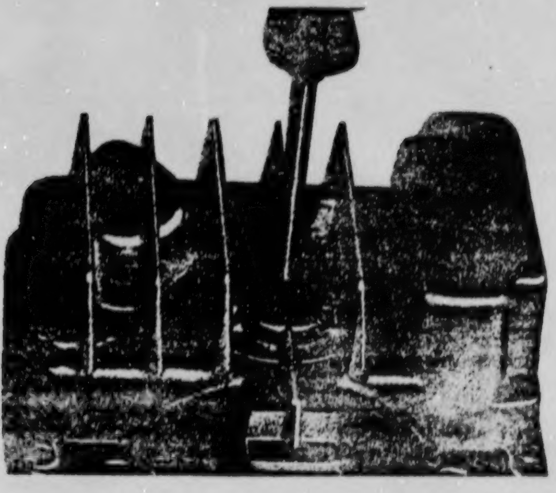

Figure 163. Adjusting Transistor Voltage Regulator Setting.

Because of the many different types of transistor regulators that are manufactured, always be sure to obtain the appropriate technical order or manual to prevent damage to the regulator's transistors when working on the charging system.

WIRING SERVICE

A visual inspection will often reveal much useful information relative to the condition of the charging system. All wiring should periodically be visually inspected for frayed or damaged insulation. Faulty wiring should be replaced. All terminals should be checked for loose or corroded connections. High resistance resulting from loose or corroded connections between the alternator and the battery will cause a lowering of the charging rate to the battery. Terminals should be cleaned and tightened if necessary.

TROUBLESHOOTING THE AC CHARGING SYSTEM

Alternator charging systems are completely different from the direct current charging system circuits previously studied. Therefore, none of the troubleshooting checks used for the direct current systems can be used for the AC systems. Before attempting to troubleshoot, it is wise to observe the following precautions. Failure to do so can result in burned out alternator diodes and vehicle wiring.

1. When installing a battery, always make absolutely sure the ground polarity of the battery and the ground polarity of the alternator are the same. If a battery of the wrong polarity is connected into the charging system or if the battery is reversed when installing it, the battery is directly shorted through the diodes. Consequently, the diodes and the vehicle wiring are endangered by high current flow. Burned wiring harness and burned "open" diodes probably will be the result.

2. When connecting a booster battery, make certain to connect the negative battery posts together and the positive battery ports together. Failure to observe this precaution will result in the same damage as previously described.

3. When connecting a charger to the vehicle, connect the battery charger positive lead to the positive battery post and the charger negative lead to the negative post of the battery. Failure to follow this procedure will result in the same damage described in (1).

4. Never operate the alternator on an open circuit. With no battery or electrical load in the circuit (open circuit), the alternator can build up high voltage which may damage the diodes and could be extremely dangerous to anyone who might accidentally touch the alternator battery terminal. Before making tests or on-the-vehicle checks, it is wise to make sure that all connections in the circuit are clean and tight.

5. Do not short across or ground any terminals on the alternator or regulator. Any circuit purposely set up by grounding or shorting any of the alternator or regulator terminals can cause serious electrical malfunctions that might endanger components of the electrical system.

6. Do not attempt to polarize the alternator. Unlike the DC generator, the alternator's polarity cannot be lost or changed. An attempt to polarize, therefore, can be of no value and can cause damage to the alternator diodes, wiring harness, and other systems.

Complaints or troubles involved in the charging system are generally either an overcharged battery or an undercharged one. These complaints can generally be quickly corrected.

Overcharged Batteries

A battery that is being overcharged is detected by excessive water usage. In cases of extreme overcharge, the electrolyte level may be far below the top of the plates. Since only the portion of the plates that is covered with electrolyte is useful in developing voltage, the battery may not have sufficient capacity to crank the engine. Furthermore, a certain amount of permanent damage is done. Water usage in these cases exceeds the normal usage of one ounce of water per cell each 1,000 miles of driving. In cases where overcharging is caused by extremely high system voltage, the high voltage may also be damaging to voltage sensitive accessories such as light bulbs. To correct this situation and to correct the overcharged battery condition, the system voltage must be lowered by either an adjustment of the voltage regulator or correction of any trouble in the charging circuit. Check in order: The battery condition, wiring, voltage regulator.

Undercharged Batteries

An undercharged battery is one that "runs down" or becomes discharged because of insufficient capacity to develop sufficient voltage to crank the engine or power the electrical accessories. There will be almost no water usage in these cases. To correct the undercharged condition, which will shorten battery life, the system voltage must be raised by either an adjustment of the voltage regulator or the correction of trouble in the charging system. Check the following in order when looking for the causes of an undercharged battery: Fan belt tension, battery condition, charging system wiring, alternator output, and then the voltage regulator.

SUMMARY

The alternator produces electricity by magnetic induction. The conductors are cut by magnetic lines of force as the rotor is rotating within the stator. To start the production of electricity, the alternator requires current from the battery to flow through the windings of the rotor, producing a magnetic field in the poles of the rotor. The pole pieces of the rotor do not have residual magnetism as the pole pieces of a DC generator have. Since the rotor poles alternate north and south, when rotating, the current produced is AC current. Diodes, or rectifiers, change the AC current produced in the stator windings to DC current for the vehicle's use. A voltage regulator controls field current flow to the rotor to limit the maximum safe voltage output from the alternator. The AC charging system does not use a cutout relay or a current regulator.

Questions

1. What is the significant advantage of the alternator in comparison to the DC generator?

2. What is the purpose of the windings of the alternator stator?

3. Of what three main units does the alternator system consist?

4. What are the main components of an alternator?

5. The stator is compared to what component in the DC generator?

6. What difference is there in the field windings of a DC generator and the field windings of the rotor in the alternator?

7. What cools the heat generated by the rectifiers?

8. How is the rotor shaft supported and what lubrication is provided?

9. In the DC generator current that is generated in the armature is AC. This AC is converted to DC through the commutator and brushes. What unit in the alternator converts AC to DC?

10. Where are the diodes mounted (as studied in this lesson) in the alternator?

11. What is the purpose of the voltage regulator?

12. Why is a transistor regulator preferred over a vibrating contact point regulator?

13. What is the purpose of the field relay unit in the alternator regulator?

14. How is arcing of the voltage regulator points reduced?

15. What component within the alternator prevents the battery from discharging back through the alternator?

16. To have maximum current flow to the rotor coil, the moveable regulator point must be touching which fixed position?

17. What is used to check the diodes in an alternator?

18. What is used to check transistor regulators?

19. What should be used to clean dirty regulator contact points?

20. What should be checked if the battery is continually being overcharged?

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ATC276

PREPARE THE MAN

WORKBOOK 3ABR47330-WB-300

Technical Training

Mechanic

General Purpose Vehicle Repairman

BLOCK III
AUTO ELECTRICAL UNITS

16 October 1972

AIR TRAINING COMMAND

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-WB-300, 13 August 1970.
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304	DC Charging System	29
305	AC Charging System	35

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-WB-301

FUNDAMENTALS OF AUTOMOTIVE ELECTRICITY, BATTERIES, AND BASIC ELECTRICAL CIRCUITS

OBJECTIVES

Upon completion of this workbook you will be able to:

Identify various electrical symbols and explain their meaning.

Construct electrical circuits and measure voltage, amperage and resistance in the circuits.

Inspect, service and test automotive batteries.

EQUIPMENT

	Basis of Issue
Auto Electrical Board	1/student
Batteries	1/student
Hydrometer	1/student
Battery-Starter Tester	1/2 students
Hand Tools	1/student
Special Tools	1/student

PROCEDURE

Using this workbook as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Identify electrical symbols.

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PROCEDURE

1. Identify each of the electrical symbols in figure 1.

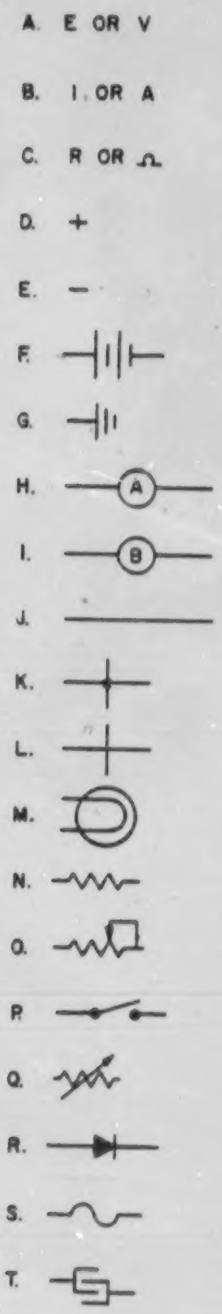
A. E OR V
B. I OR A
C. R OR Ω
D. +
E. −
F.
G.
H.
A
I.
B
J.
K.
L.
M.
N.
O.
P.
Q.
R.
S.
T.

Figure 1. Electrical Symbols.

IMPORTANT INFORMATION

1. In electrical work, symbols are used in diagrams to represent equipment, devices and conductors. In the space write the correct name of the symbols in figure 1.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

k. ______________________

l. ______________________

m. ______________________

n. ______________________

o. ______________________

p. ______________________

q. ______________________

r. ______________________

s. ______________________

t. ______________________

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Exercise 2

Construct a series circuit, measure voltage and amperage at various points in the circuit.

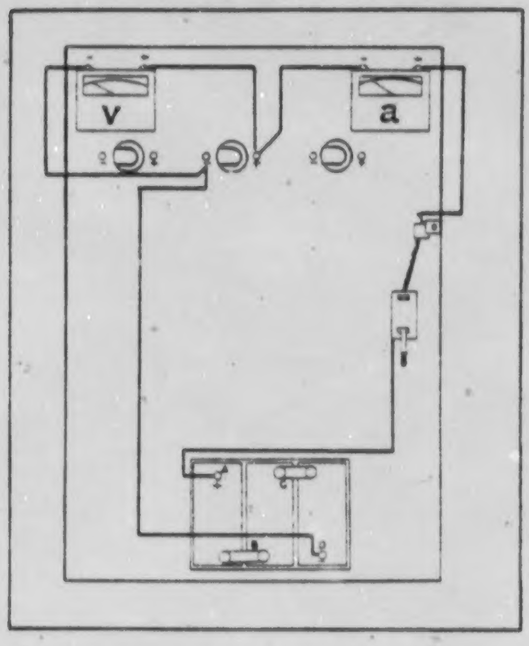

Figure 2. Series Circuit Using One Light Bulb.

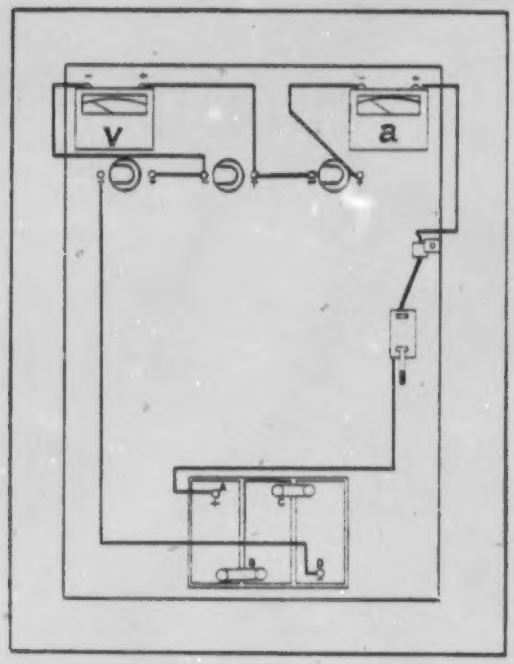

Figure 3. Series Circuit Using Three Light Bulbs.

PROCEDURE

1. Connect a series circuit with one light bulb as shown in figure 2.
2. Connect an ammeter in the circuit and note the amount of amperage.
3. Connect a voltmeter in the circuit and note the amount of voltage.
4. Observe the brightness with which the light bulb burns and the heat produced by the bulb.

IMPORTANT INFORMATION

1. Remember! In a series circuit, current flows in a single path.
2. Ammeters are always connected in series. Amperage: ________
3. Voltmeters are always connected in parallel or across the circuit. Voltage: ____________
4.

5. Read paragraph 5 in the information column.	5. During this test the lighl bulb furnishes the resistance for the circuit. The voltage applied to the light bulb is about equal to full battery voltage. The resistance of the light bulb allowes the voltage of the battery to force only a certain amount of current through the circuit. This bulb is made to operate on 12 volts and should burn to its full brightness.
6. Connect the three light bulbs on the trainer in a series circuit as shown in figure 3.	6.
7. Read the meters and record their readings in the spaces.	7. Volts: ____________ Amps: ____________
8. Observe that the light bulbs burn rather dimly.	8.
9. Read paragraph 9 in the information column.	9. In this series circuit, the electric current flows through the resistances of the three light bulbs. The total current flow is less than in the previous circuit where only one bulb was used. Also, the light bulbs do not burn to full brightness due to the smaller current flow.

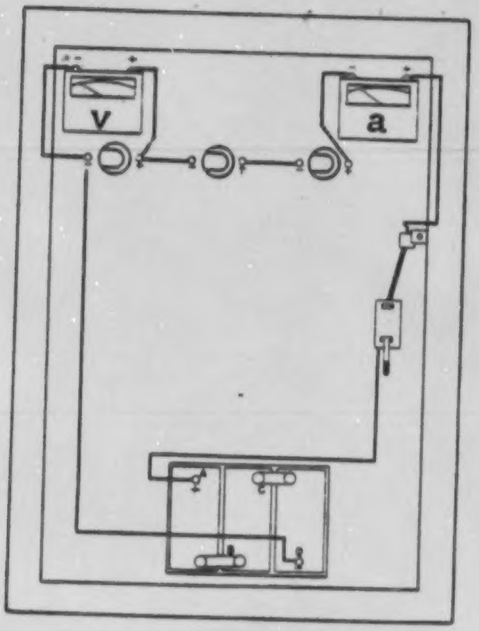

Figure 4. Measuring Voltage Applied to One Light Bulb.

10. Change the voltmeter leads to the position shown in figure 4.	10. This measures the voltage applied to the terminals of one light bulb.
11. Read the voltmeter and record the meter reading.	11. Volts (one bulb): __________
12. Remove the voltmeter leads from the terminals of the one light bulb and touch them to the terminals of the second light bulb.	12.
13. Read voltmeter and record the reading.	13. Volts (second bulb): __________
14. Remove the voltmeter leads from the second bulb and touch them to the terminals of the third light bulb.	14.
15. Read voltmeter and record the reading.	15. Volts (third bulb): __________
16. Read paragraph 16 in the information column.	16. When current flows through resistances such as the light bulbs in the circuit, a voltage loss occurs. In this test, the voltage measured at the terminals of each light bulb is the amount of loss within that bult. The sum of all voltage losses in a circuit is equal to total voltage applied to the circuit at its source (in this case, the battery).

Exercise 3

Construct parallel and series-parallel circuits and measure their voltage and amperage.

PROCEDURE	IMPORTANT INFORMATION
1. Connect a parallel circuit on the trainer as shown in figure 5.	1.
2. Read the meters and record their readings in the space.	2. Volts: ________ Amps: ________
3. Note the brightness with which the bulbs burn.	3.

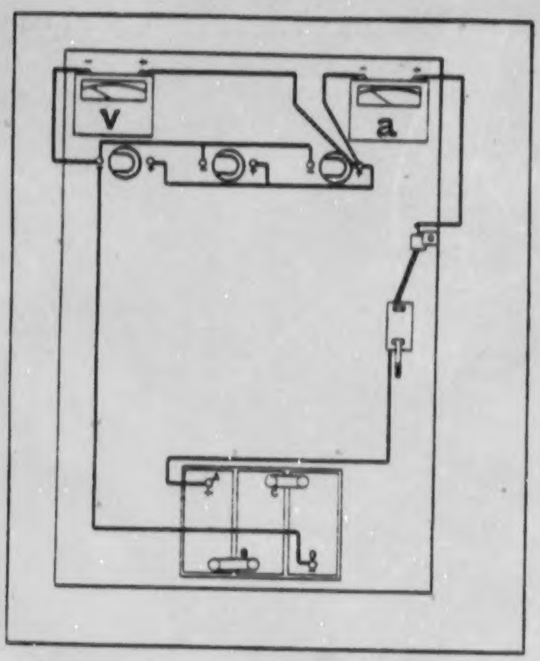

Figure 5. Three Light Bulbs in Parallel.

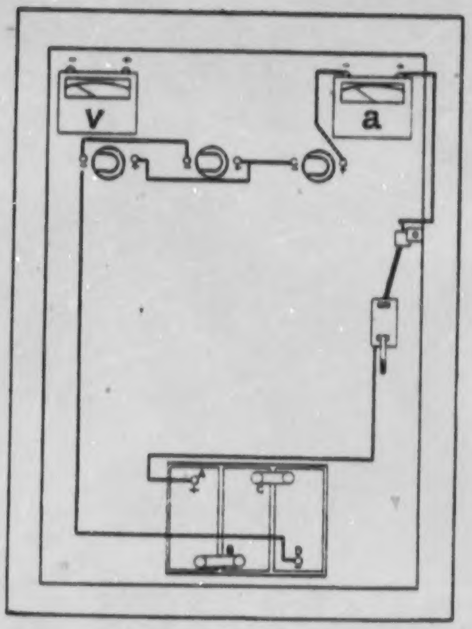

Figure 6. One Bulb in Series; Two Bulbs in Parallel.

4. Determine why the light bulbs draw more current when connected in parallel.	4.
5. Read paragraph 5 in the information column.	5. During this test the same voltage is applied to the terminals of all units connected in a parallel circuit. In this case, the units are light bulbs; each one is conducting current in exactly the same manner as when connected in a circuit by itself. The total current flow, as measured by the ammeter, is equal to the current flow of all light bulbs added together. The total resistance of the circuit is less than the resistance of one light bulb by itself.
6. Connect a series-parallel circuit on the trainer as in figure 6.	6.
7. Read the ammeter and observe the brightness of the light bulbs.	7.

8.	Record the readings in the space.	8.	Amperes: ____________
9.	Read paragraph 9 in the information column.	9.	In this series-parallel circuit, two of the light bulbs are in parallel and the other bulb is in series. All of the current that flows in the circuit must flow through the series bulb. Therefore, the series bulb burns brighter than the parallel bulbs. If the series bulb goes out, all the bulbs will go out.

Exercise 4

Clean and service batteries.

	PROCEDURE		IMPORTANT INFORMATION
1.	Practice all safety precautions applying to the project.	1.	
2.	Clean and inspect the battery.	2.	Caution: When removing battery from vehicle or trainer, always disconnect the grounded cable first.
a.	Clean terminals and clamps. Note: Negative post has smaller diameter. Positive post has the larger diameter.	a.	Corrosion should be removed periodically from the terminals and clamps. Clean with cleaning tool.
b.	Clean holder and battery top.	b.	Use wire brush and baking soda solution for cleaning the holder. When cleaning the battery top, the battery vent plugs should be tightened and the battery top sprinkled with soda solution. When the baking soda solution has stopped foaming, flush top with clean water. Caution: Make sure that none of the solution gets into the battery.
c.	Inspect the battery.	c.	Check for cracked case, bulged case, electrolyte level, etc.

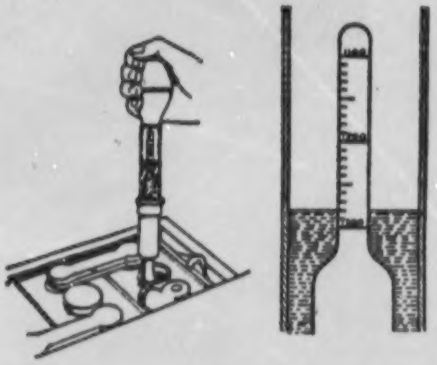

Figure 7. Taking Specific Gravity Reading of a Battery With Battery Hydrometer. (A Closeup View of 1280 Reading is Shown at the Right.)

Exercise 5

Test a battery.

	PROCEDURE		IMPORTANT INFORMATION
1.	Use the battery hydrometer to test specific gravity of each cell IAW TO 33D6-3-4-1, page 12.	1.	Refer to figure 7.
2.	Record the reading in the spaces provided.	2.	Cell #1: _____ 2: _____ 3: _____ 4: _____ 5: _____ 6: _____ Note: Electrolyte burns the skin if left in contact for any length of time. It also destroys clothing, therefore BE CAREFUL!
3.	Perform the battery capacity test IAW TO 33D6-3-4-1, page 13.	3.	Refer to figure 8 for proper connections of the Y-20 Battery-Starter Tester.
4.	Have the instructor check your project.	4.	Instructor's Initials: ________

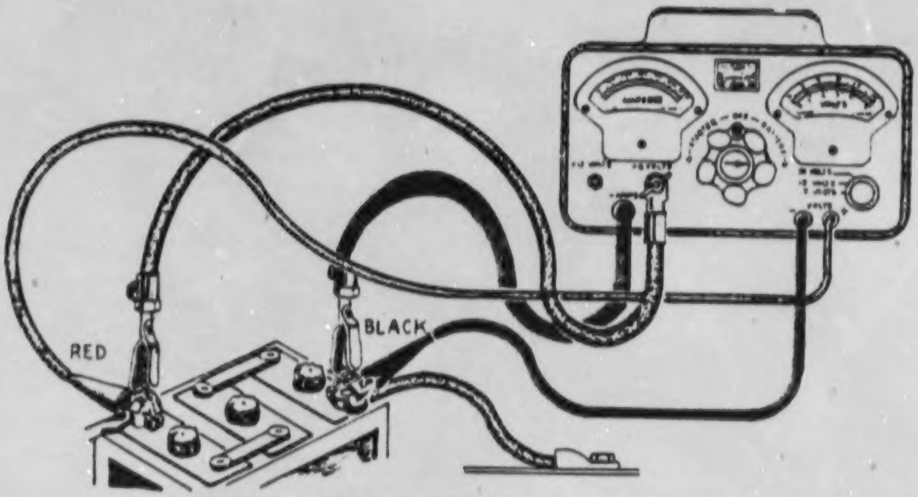

Figure 8. Battery Capacity Test.

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-WB-302

BATTERY AND MAGNETO IGNITION SYSTEMS

OBJECTIVES

Upon completion of this workbook you will be able to:

Identify units of the ignition system and explain their purpose.

Repair and service ignition system components.

Check, adjust and/or isolate malfunctions in the ignition system.

EQUIPMENT

	Basis of Issue
Bench Items	1/student
Universal Diagnostic Tester (UDT)	1/2 students
Tach-Dwell Tester	1/2 students
Volts-Amp Tester	1/2 students
Timing Light	1/2 students
Oscilloscope	1/3 students
Spark Plug Cleaner	1/6 students
Common Tools	1/student

PROCEDURE

Using this workbook as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Perform coil tests using the Universal Diagnostic Tester (UDT).

PROCEDURE	IMPORTANT INFORMATION
1. Practice all safety precautions applying to the project.	1.
2. Obtain technical publication.	2. Refer to TO 33D6-3-4-1, pages 108-111.
3. Perform all coil tests.	3. Handle this equipment with care.

Exercise 2

Perform condenser tests using the Universal Diagnostic Tester (UDT).

PROCEDURE	IMPORTANT INFORMATION
1. Practice all safety precautions applying to the project.	1. Remember! Think safety--Practice safety--Act safely!
2. Obtain technical publication.	2. Refer to TO 33D6-3-4-1, pages 81 and 82. Note: Numerous illustrations contained therein are very valuable.
3. Test the condenser.	3. Handle this equipment with care.

Exercise 3

Remove, service, test and replace spark plugs.

PROCEDURE	IMPORTANT INFORMATION
1. Practice all safety precautions applying to the project.	1.
2. Remove secondary wires from the spark plugs.	2. Use proper tools while performing this procedure.
3. Remove spark plugs using special spark plug socket.	3. Care should be taken not to damage porcelain of spark plugs. They are easily broken.
4. Wipe the spark plug clean.	4.

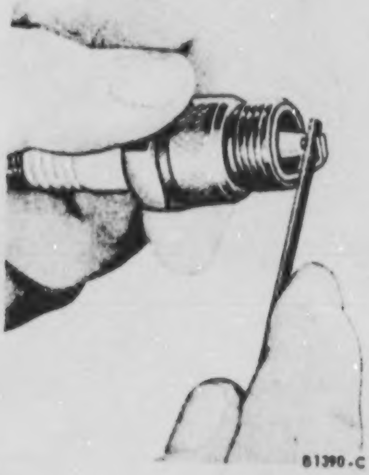

Figure 9. Filing Spark Plug Electrodes Square.

5. Square off the electrode with a file, as shown in figure 9.	5.
6. Clean spark plugs, electrodes and insluator.	6. Procedure for cleaning and testing spark plugs will be shown bv the instructor. Note: Clean porclain as required and make sure electrodes are filed square.
7. Use air pressure to clean away loose particles from spark plugs.	7. Use protective garment and goggles for protection of eyes.

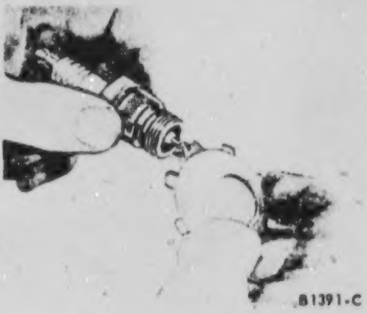

Figure 10. Gapping Spark Plugs.

8. Adjust air gap between center and ground electrodes as shown in figure 10.	8. Use proper feeler gauge and obtain specifications from vehicle manual.
9. Test spark plugs.	9.
10. Replace spark plugs in engine.	10.
11. Connect secondary wires to spark plugs.	11. Refer to manufacturer's specification for correct firing order.
12. Start the engine.	12. Listen and observe engine for cylinder missing or backfiring and recheck to see if you have rewired ignition system in the correct sequence.
13. Stop the engine.	13.

Exercise 4

Adjust ignition points.

	PROCEDURE		IMPORTANT INFORMATION
1.	Remove the distributor cap.	1.	On conventional distributors, unsnap metal clips that hold distributor cap in place.
2.	Remove rotor.	2.	
3.	Adjust ignition point.	3.	
	a. Rotate distributor shaft until rubbing block on movable contact is on high point of cam lobe.		a.
	b. Obtain the proper gap, using the appropriate tool or instrument for gauging.		b. Use publication to obtain proper setting.
	c. Loosen hold-down screw of stationary ignition point.		c.
	d. Rotate adjusting screw until proper setting has been obtained.		d. Contact points should grip feeler gauge lightly (if gauge is used).
	e. Recheck ignition points to insure proper setting.		e.
4.	Have the instructor check the project.	4.	Instructor's Initials: _______

Exercise 5

Time engine by timing marks.

	PROCEDURE		IMPORTANT INFORMATION
1.	Practice all safety precautions applying to the project.	1.	
2.	Perform preoperation inspection.	2.	Check fuel, oil and coolant levels.

3. Remove #1 spark plug.	3. Use spark plug socket. Care should be used not to break spark plug porcelain insulator.
4. Position #1 piston on top dead center of compression stroke.	4. Place the thumb over spark plug hole and crank engine over slowly with the starter and feel for compression. Caution: Turn the engine with short jabs on the starter switch to prevent going past TDC (top dead center) and past the timing mark, figures 11, 12 and 13.

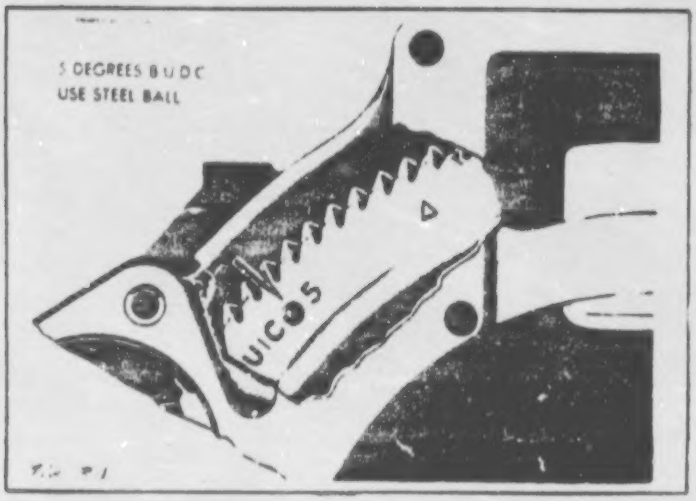

Figure 11. Flywheel Timing Mark.

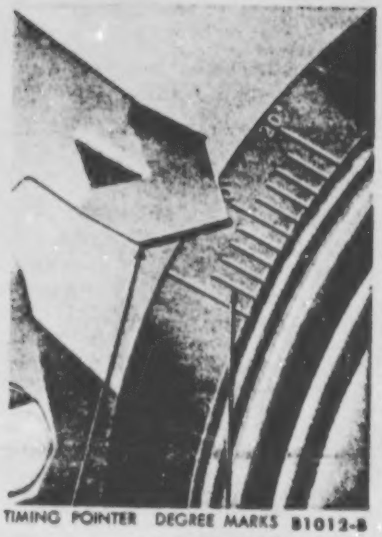

Figure 12. Typical Pulley Mounted Degree Marks.

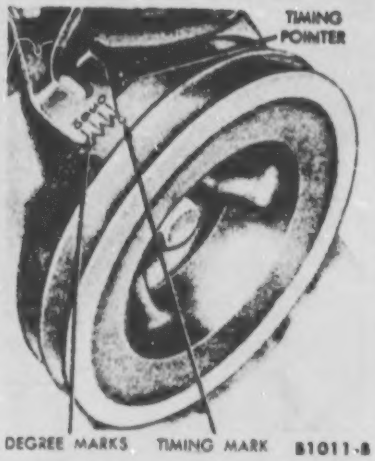

Figure 13. Typical Pointer Mounted Degree Marks.

5. Line up the timing mark with the pointer. Turn the crankshaft of the engine until the ignition timing mark is in line with the pointer.	5.
6. Position distributor rotor in accordance with the vehicle manual.	6.
7. Position distributor cap so #1 wire well is directly in line with the rotor arm.	7. With distributor cap in position, you may use a chalk mark on the body of the distributor in line with the #1 wire well in the distributor cap. If the distributor cap is removed, you should turn the body of the distributor until the rotor is in line with the chalk mark. When the cap is replaced, the rotor should line up with the #1 wire well. With the rotor in this position, the points should be just breaking. This can be checked by turning on the ignition switch and sparking the primary wire against the distributor

	primary terminal post. You should then turn the body of the distributor slightly until no spark occurs. Now you may lock the distributor in position.
8. Replace spark plug wires according to rotation and firing order.	8. With the distributor cap and rotor in position, you should replace the spark plug wires according to the proper rotation and firing order. This information should be obtained from the applicable technical publication. If no publication is available, rotation of the distributor rotor can be determined by observing the movement of the rotor while the engine crankshaft is turning. On some distributors, the rotation is indicated by an arrow on the cam. Another method of determining rotation is to check the movement of the rotor against the governor weight springs. The direction the rotor moves is also the direction of rotation. Many engines have the firing order cast on the engine manifold. A popular firing order for 6-cylinder engines is 1-5-3-6-2-4 and is used on GMC, Chevrolet and Valiant engines. If in doubt, consult the manual.
9. Start the engine.	9. If the engine does not start, you may check for spark at the spark plug. Backfiring indicates the engine is not properly timed. You are now ready to set the timing accurately with a timing light.

Exercise 6

Adjust timing with a timing light.

PROCEDURE	IMPORTANT INFORMATION
1. Connect the timing light.	1. Always set timing to specifications with the use of a timing light.
a. Connect the timing light and adjust the engine timing.	a. This information is available in TO 33D6-3-4-1.

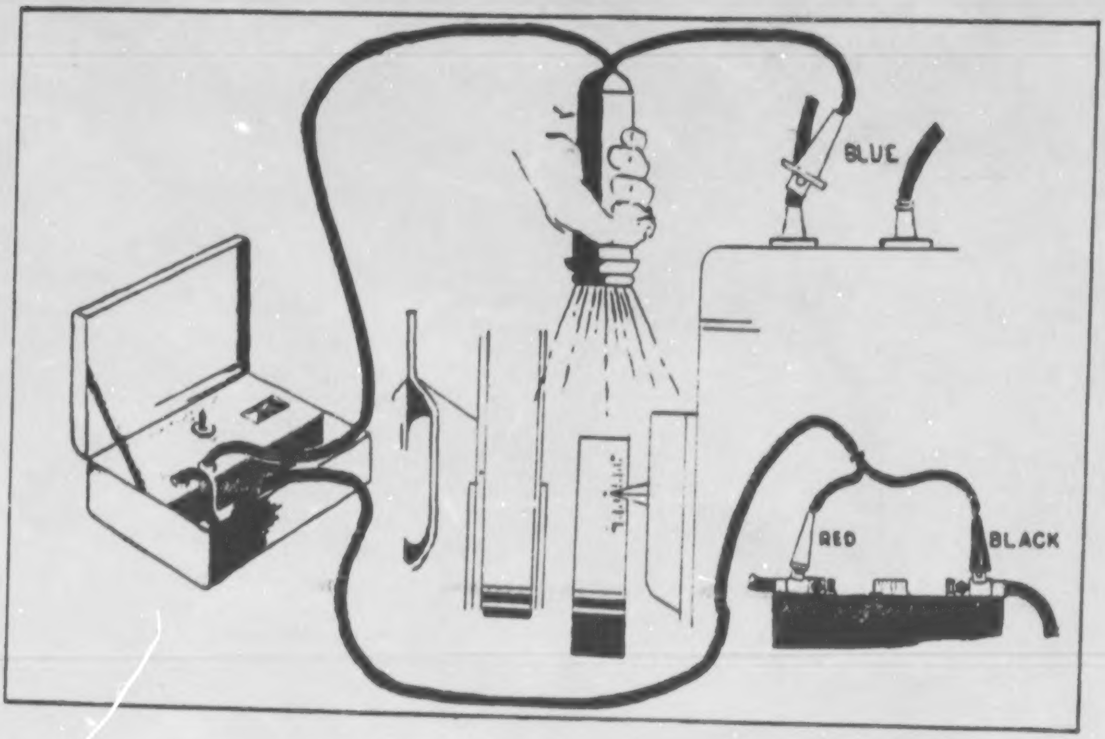

Figure 14. Timing Light Connections.

b.	Connect the battery leads of the timing light to the battery with the red clip to the positive post and black to the negative post.	b.	Refer to figure 14.
c.	Connect blue spark plug lead of the timing light to the terminal of the #1 spark plug wire at the spark plug.	c.	Caution: The engine should be stopped to prevent an electrical shock!
d.	Start engine and operate at idle speed.	d.	Refer to manufacturer's specifications.
e.	Check engine idle speed with a tachometer.	e.	On some engines equipped with a vacuum advance mechanism, it may be necessary to disconnect the vacuum advance unit. Check manufacturer's specifications.

f.	Aim timing light at timing mark.	f.	The flashing action of the timing light makes the timing mark appear to stand still.

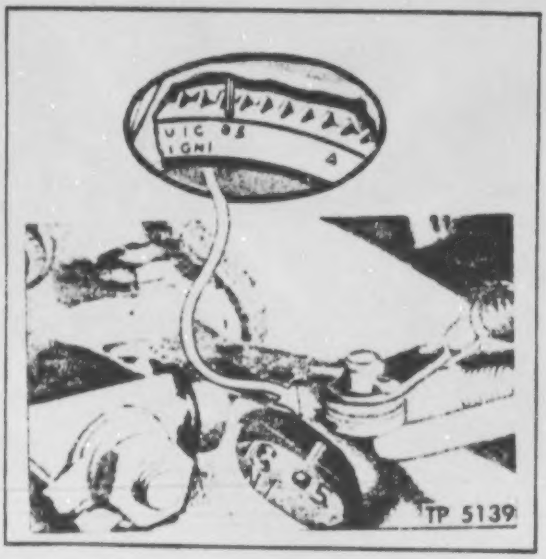

Figure 15. Timing Mark in Line With Pointer.

g.	Advance or retard timing as necessary.	g.	Loosen the distributor mounting screw and turn the body of the distributor until the timing mark is in line with the pointer, figure 15.
h.	Secure the distributor mounting screw.	h.	With the timing mark in line with the pointer, tighten the distributor mounting screw. The engine ignition system is now in perfect time.
i.	Remove the timing light.	i.	Stop engine before removing the timing light to avoid a shock.
2.	Have the instructor check your project.	2.	Instructor's Initials: ________

Exercise 7

Analyze engine ignition system using an oscilloscope.

PROCEDURE	IMPORTANT INFORMATION
1. Practice all safety precautions applying to the project.	1.
2. Obtain proper publications.	2.
3. Connect oscilloscope to engine.	3.
4. Perform tests as directed by the instructor.	4.
5. Have the instructor check your project.	5. Instructor's Initials: ________

Exercise 8

Disassemble and inspect the magneto (bench item, high tension type).

PROCEDURE	IMPORTANT INFORMATION
1. Observe all safety precautions applying to the project.	1.
2. Disassemble assigned magneto.	2. Make of magneto worked on: ______________________________ The magneto will be disassembled according to instructions from the instructor.
3. Inspect the component parts of the magneto.	3. All parts should be thoroughly inspected visually for serviceability. Check all electrical leads for good condition of wiring and terminals.
a. Examine breaker for condition of points.	a. Points must contact each other squarely with full contact surface. Badly pitted points require the replacement of the breaker.
b. Examine cam for wear.	b.
c. Examine the distributor contact surfaces for pitting or burning.	c.
4. Reassemble the magneto.	4.

5. Have the instructor check your project.	5. Instructor's Initials: ________

Note: Use the space provided below for additional notes pertaining to the checking of the ignition system.

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-WB-303

CRANKING MOTORS AND STARTING SYSTEMS

OBJECTIVES

Upon completion of this workbook you will be able to:

Identify components of cranking motors and starting systems and explain their purpose.

Repair and service starting system components.

Check, adjust and isolate malfunctions in the starting circuit.

EQUIPMENT

	Basis of Issue
Bench Item Starters	1/student
Armature Tester (Growler)	1/6 students
Battery-Starter Tester	1/2 students
Common Tools	1/student

PROCEDURE

Using this workbook as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Disassemble the cranking motor.

Note: The disassembly steps will vary considerably according to the type and construction of the cranking motor. The following information will apply mainly to the type of cranking motor that will be found during the time spent in the 3ABR47330 ccurse. Disassembly should proceed only so far as is necessary to make repair or replacement of the defective parts.

PROCEDURE	IMPORTANT INFORMATION
1. Select the proper tools and test equipment.	1. Always use the correct tool and use it safely.
2. Disassemble the cranking motor, figure 16.	2.
a. Disconnect starter switch (if used) or solenoid from the motor terminal on the starter frame.	a.

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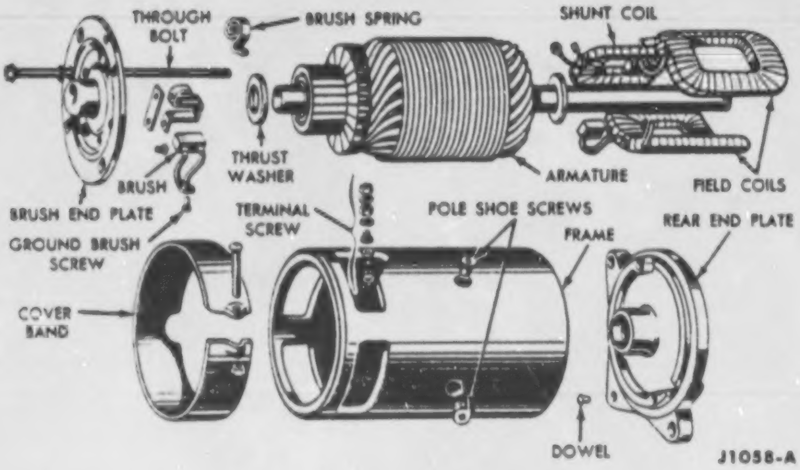
THROUGH BOLT
BRUSH SPRING
SHUNT COIL
THRUST WASHER
BRUSH
ARMATURE
FIELD COILS
BRUSH END PLATE
TERMINAL SCREW
POLE SHOE SCREWS
REAR END PLATE
GROUND BRUSH SCREW
FRAME
COVER BAND
DOWEL
J1058-A

Figure 16. Disassembled Starter Motor.

b.	Remove brushes from brush holders.	b.	Follow the directions of your instructor.
c.	Unscrew the thru bolts, figure 16, and remove the commutator end frame and field frame assembly.	c.	This will separate the drive housing.
d.	Remove the armature from the drive housing.	d.	

Exercise 2

Inspect, repair or replace parts on the cranking motor.

	PROCEDURE		IMPORTANT INFORMATION
1.	Check armature to commutator leads.	No	Make sure that they are properly soldered.
2.	Inspect the commutator.	2.	Burned commutator bars are sometimes caused by an open circuit in the armature.
a.	Clean commutator if necessary.	a.	Use 00 sandpaper for cleaning.
b.	Inspect brushes.	b.	If brushes are worn down to less than 1/2 their original length, they must be replaced. If brushes are being replaced they should be reseated as shown in figure 17.

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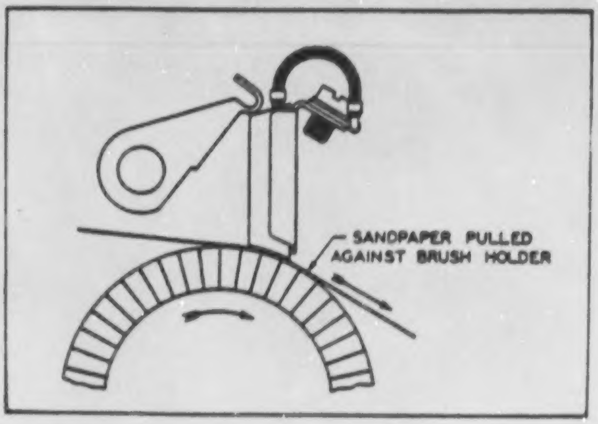

Figure 17. Reseating Brushes.

c.	Check brush spring tension.	c.	Use spring tension gauge.
d.	Examine brush holders for bent or damaged condition.	d.	
e.	Check armature for:	e.	The instructor will demonstrate these tests for you.
	(1) Short circuits.		(1) Short circuits are located by using the growler.
	(2) Open circuits.		(2) Inspect the points where the conductors are joined to the commutator bars.
	(3) Unwanted grounds.		(3) Use a test lamp and test points.
f.	Check the field windings for:	f.	The instructor will demonstrate these tests for you also.
	(1) Unwanted grounds.		(1) Use test lamp. Connect one lead to the field and the other lead to the starter frame.
			Note: If the motor has a shunt coil, the shunt coil must be disconnected before making this test.

(2) Open circuits.	(2) Connect test lamp leads to ends of the field coil.

Exercise 3

Reassemble and test the cranking motor.

PROCEDURE	IMPORTANT INFORMATION
1. Reassemble the cranking motor.	1. Reassemble in the reverse procedure of that used in the disassembly, figure 16. Make sure that all leads are correctly attached and that brushes are installed in holders and making contact with the commutator of the armature.

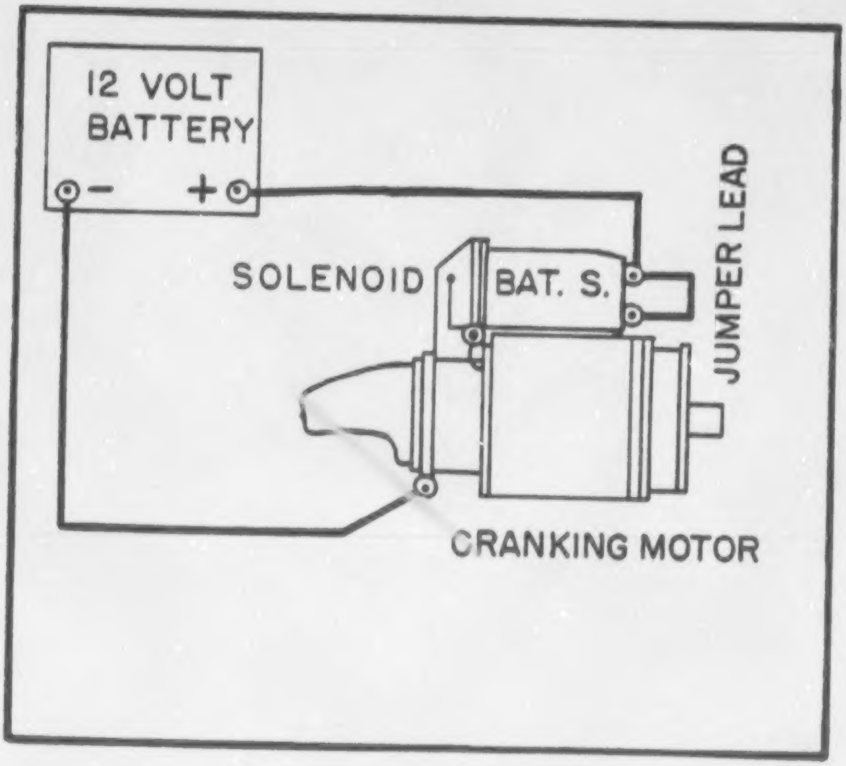
12 VOLT BATTERY
−
+
SOLENOID
BAT. S.
JUMPER LEAD
CRANKING MOTOR

Figure 18. Circuit for Checking Free Speed of Cranking Motor.

2. Motor the cranking motor.	2. After reassembly, connect a battery to the cranking motor terminal and ground, figure 18. Energize the solenoid (if any) by connecting a jumper lead between the battery terminal and the "S" terminal on the solenoid. The cranking motor should rotate freely.
3. Have the instructor check your work.	3. Instructor's Initials: ______

Exercise 4

Test the starting circuits on the vehicle.

PROCEDURE	IMPORTANT INFORMATION
1. Make the checks for excessive resistance in the cranking motor's insulated and ground circuits in accordance with TO 33D6-3-4-1, pages 16-18.	1.
2. Make the starter amperage draw test.	2. Use TO 33D6-3-4-1, page 19.
3. Have the instructor check your project.	3. Instructor's Initials: ______

Note: Use the space provided below for any additional notes on the maintenance and testing of the cranking motor.

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-WB-304

DC CHARGING SYSTEM

OBJECTIVES

Upon completion of this workbook you will be able to:

Identify units of a DC charging system and explain their function.

Repair and service DC generators and DC charging system components.

Check, adjust and isolate malfunctions in a DC charging system.

EQUIPMENT

	Basis of Issue
Bench Item Generators	1/student
Bench Item Regulators	1/student
Armature Tester (Growler)	1/6 students
Volts-Amp Tester	1/2 students
Tach-Dwell Tester	1/2 students
Spring Tension Gauge	1/6 students
Common Tools	1/student

PROCEDURE

Using this workbook as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Partially disassemble the generator.

PROCEDURE	IMPORTANT INFORMATION
1. Partially disassemble the generator.	1. The procedure to be followed will vary according to the generator construction. Note: Disassembly should proceed only so far as is necessary to make repair or replacement of the defective parts.
a. Remove thru bolts.	a.
b. Remove commutator end frame.	b. End frame may have to be loosened by lightly tapping edge with a plastic hammer.
c. Remove armature assembly.	c. Armature, pulley, fan, and drive end frame are removed as an assembly.

Exercise 2

Bench test and service the disassembled generator.

PROCEDURE	IMPORTANT INFORMATION
1. Check the armature.	1. If coils are loose in slots or unsoldered from commutator, the armature should be replaced.
2. Check and clean the commutator.	2. If the commutator is badly seared it should be turned; if slightly worn or dirty, it should be sanded with 00 sandpaper.
3. Test armature for:	3.
a. Short circuits.	a. Use a growler for this check. Place in growler and slowly revolve while a hacksaw blade is held above the armature core. Short circuits will cause the blade to vibrate against the core when it is held above the slot containing the shorted winding.
b. Unwanted grounds.	b. Use test lamp with test prods. Place one test prod on the core of the armature and the other on the commutator. If lamp lights, the armature is grounded.
c. Open circuits.	c. Open circuits in the armature are usually readily apparent. This condition causes burned commutator bars. Growler may be used for checking.
4. Test generator fields and terminals for:	4.
a. Unwanted grounds.	a. Use test lamp prods on field terminal and frame. If lamp lights, the field is grounded.
b. Open circuits.	b. Place test lamp prods at two ends of field circuit. The lamp should light. If it does not light, the field circuit is open.

c.	Short circuits.	c.	Connect fields in series with an ammeter and a battery of the specified voltage. Field current draw should be approximately 1.5 amps for a 12 volt system.
5.	Check brush holders.	5.	Where located, check for security of mounting and the insulated brush holder for grounds.

Exercise 3

Reassemble and make brush spring tension test.

Fig. [illegible]

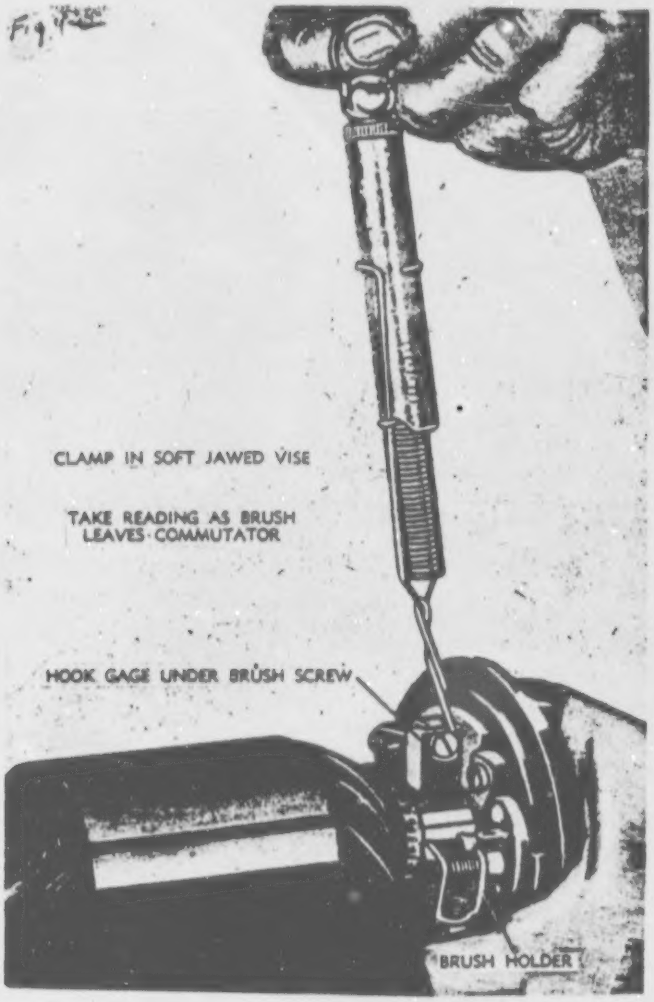
CLAMP IN SOFT JAWED VISE
TAKE READING AS BRUSH LEAVES COMMUTATOR
HOOK GAGE UNDER BRUSH SCREW
BRUSH HOLDER

Figure 19. Measuring Brush Spring Tension on Generator With Tension Gauge.

PROCEDURE	IMPORTANT INFORMATION
1. Reassemble the generator.	1. Reassembly is the reverse of disassembly.
2. Check brush spring tension as shown in figure 19.	2. Tension is checked by measuring with a spring ounce gauge the pull required to raise brushes, brush arms, or holders from the contact position. Replace the springs if the tension is not as specified. Spring tension found: ______________

Exercise 4

Bench test reassembled generator.

PROCEDURE	IMPORTANT INFORMATION
1. Observe all safety	1.
2. Make a motoring test.	2. Note: Connected properly, the generator should motor at a steady speed if everything is operating properly. Refer to figures 20 and 21 for correct connections.
a. Make the correct connections for motoring test on an "A" circuit generator, figure 20.	a.
b. Make the correct connections for motoring test on a "B" circuit generator, figure 21.	b.
3. Have the instructor check your project.	3. Instructor's Initials: ________

Exercise 5

Check out the charging circuits and adjust the units in the generator regulator.

PROCEDURE	IMPORTANT INFORMATION

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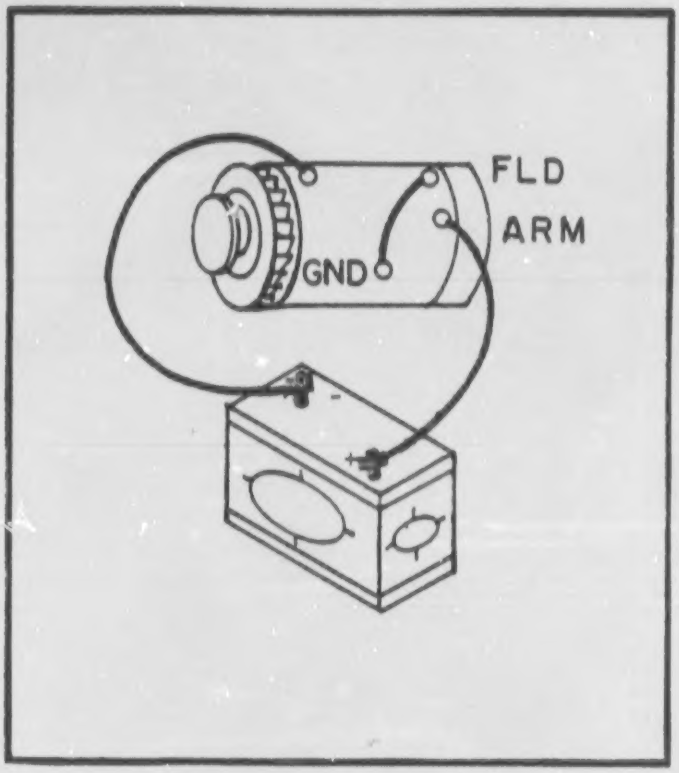

Figure 20. Connections for Running Generator ("A" Circuit) as a Motor.

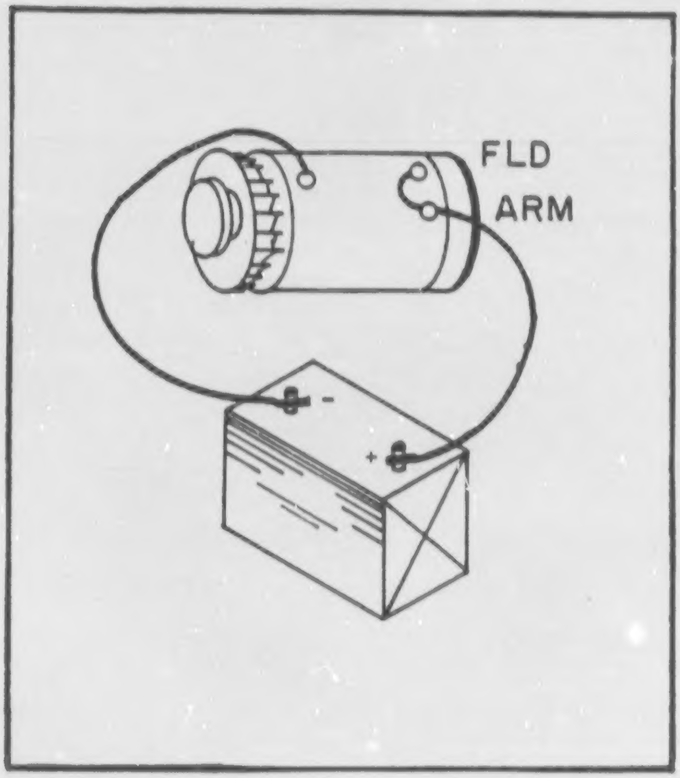

Figure 21. Connections for Running Generator ("B" Circuit) as a Motor.

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1.	Observe all safety precautions applying to the project.	1.	
2.	Obtain the applicable publications.	2.	List references used: ________ ______________________________ ______________________________
3.	Check out the charging circuit and adjust the applicable test equipment.	3.	Because of the different types of test equipment that may be used, always refer to the applicable publications for the correct procedure.
4.	Have the instructor check your work.	4.	Instructor's Initials: ________

Note: Use the space provided below for notes pertaining to the checking of the DC charging circuit.

AC CHARGING SYSTEM

OBJECTIVES

Upon completion of this workbook you will be able to:

Identify units of an AC charging circuit and explain their function.

Repair and service AC charging system components.

Check, adjust and isolate malfunctions in an AC charging circuit.

EQUIPMENT

	Basis of Issue
Bench Item Alternators	1/student
Bench Item Regulators	1/student
Diode Tester	1/12 students
Tach-Dwell Tester	1/2 students
Volt-Amp Tester	1/2 students
Belt Tension Gauges	1/6 students
Common Tools	1/student

PROCEDURE

Using this workbook as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Disassemble an alternator.

Note: The following information concerns the Chrysler built alternator system. Although other manufacturer's will vary the design, location of components, and test procedures, the principle is the same. Always refer to the factory manuals for correct test procedures and specifications.

1. Remove brush assemblies.	1. To prevent possible damage to the brush assemblies, they should be removed before proceeding with the disassembly of the alternator. Refer to figures 22 and 23.

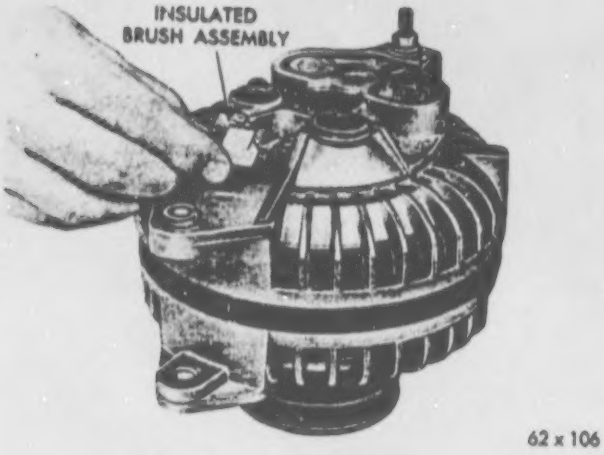

Figure 22. Removing or Installing Insulated Brush.

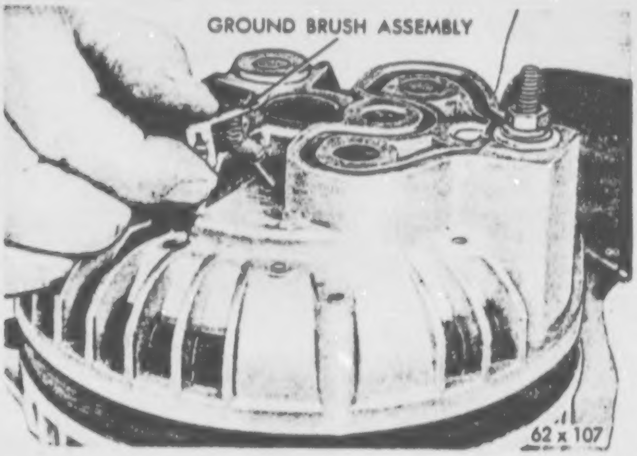

Figure 23. Removing or Installing Ground Brush.

a.	Remove insulated brush. Remove retaining screw, lockwasher, nylon washer, and field terminal.	a.	The insulated brush is mounted in a plastic holder that positions the brush vertically against one of the slip rings, figure 22. Carefully lift the plastic holder containing the spring and insulated brush assembly from the end housing.
b.	Remove insulated brush. Remove the retaining screw and lift the clip,	b.	The ground brush is placed against the remaining slip ring and is retained in a

	spring and brush assembly from the end housing.		holder that is integral with the end housing, figure 23. Use the same precaution as when removing the insulated brush.
2.	Remove the thru bolts.	2.	

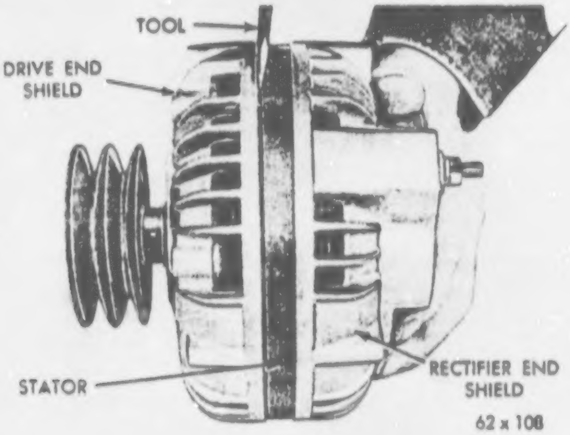

Figure 24. Separating Drive End Shield From Stator.

3.	Separate the drive end housing pulley and rotor assembly from the stator and rectifier end housing assembly.	3.	CAUTION: The stator is separated with the rectifier end frame to prevent damage to wiring, figure 24.

Exercise 2

Inspect the alternator.

	PROCEDURE		IMPORTANT INFORMATION
1.	Inspect slip rings for indications of oil, being burnt or worn.	1.	
2.	Inspect brushes for signs of sticking in holder or housing.	2.	
3.	Inspect the bearing surfaces of the rotor shaft at the rectifier end and the bearing.	3.	
4.	Inspect rectifier (diode) leads, especially at connections for good contact, also inspect insulation.	4.	

Exercise 3

Testing rectifier (diodes) and stator assembly.

1. Testing positive case diodes in the heat sink.	1. Special tool or diode tester is used to test the diode rectifiers without opening the "Y" connection. Due to the short leads at the "Y" connection it is difficult to separate them. The tester will save time and is accurate.

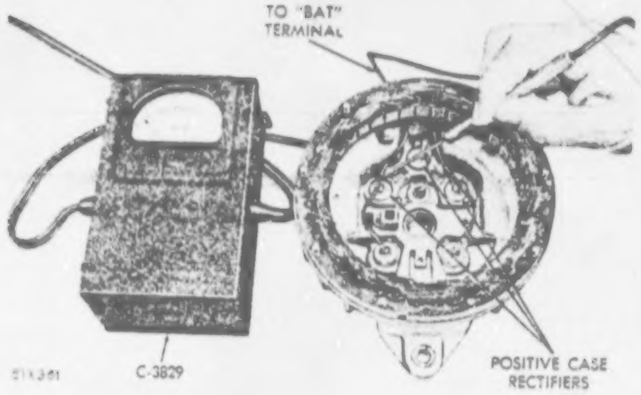

Figure 25. Testing Positive Rectifiers (Typical).

a. Plug diode tester into 110-volt supply.	a. Refer to figure 25.
b. Connect alligator clip of tester to the alternator "BAT" terminal.	b. Caution: Insulate alternator from metal bench during test.
c. Touch the bare metal of each of the positive case diode lead wires in the heat sink at the diodes.	c. Always contact the connection nearest the diodes.
d. Read the meter.	d. The reading for each diode should be the same. The reading on the meter will indicate two or over for good diodes.

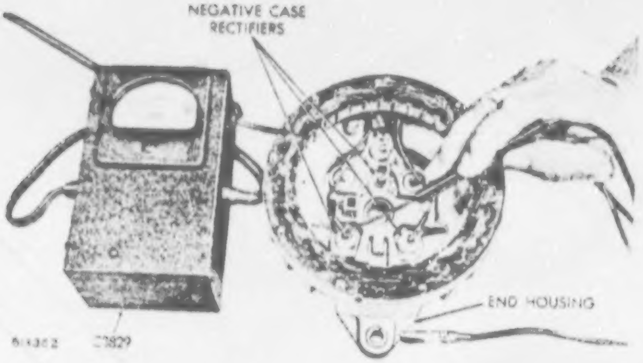
NEGATIVE CASE RECTIFIERS
END HOUSING
61x362
C2829

Figure 26. Testing Negative (Typical).

2. Test negative case diodes in the end housing.	2. Refer to figure 26.
a. Connect alligator clip of diode tester to the end housing.	a.
b. Touch the test prod to the base wire of the diode leads at the diodes.	b.
c. Meter will indicate the condition of the diodes.	c. The test indications are the same for the negative case diodes as for the positive case diodes in the heat sink. However, the meter will read at the opposite end of the scale. Refer to item 1d above.

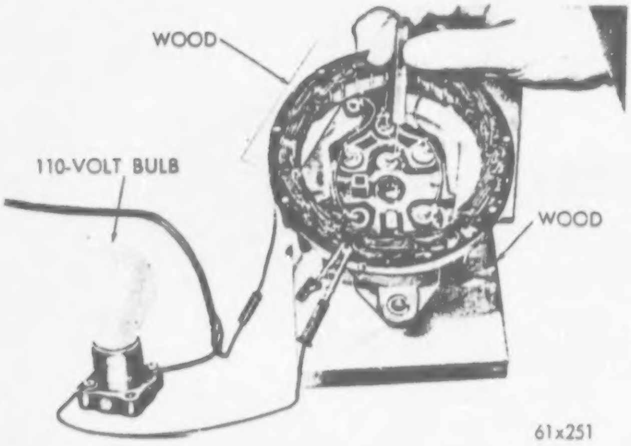
WOOD
110-VOLT BULB
WOOD
61x251

Figure 27. Testing Stator For Grounds (Typical).

3. Test the stator for grounds.	3. Refer to figure 27.
a. Connect one prod of the test lamp to the stator core, and contact the other prod to each of the three stator leads.	a. The test lamp should not light. If the test lamp lights, the stator windings are grounded.
4. Test the stator windings for open circuits.	4.
a. Contact one prod of the test lamp to all three stator leads at the "Y" connection.	a.
b. Contact each of the three stator leads at the other end.	b. The test lamp should light when the prod contacts each of the three leads. If the test lamp does not light, the stator winding is open.
5. Test the rotor for grounds.	5.
a. Contact one prod of the test lamp to one of the slip rings.	a.
b. Contact the rotor shaft with the remaining test prod.	b. The test lamp should not light. If the lamp does light, this indicates that the rotor field coil is grounded.
6. Test the rotor for opens, shorts and excessive resistance.	6. These three checks can be made in one step.
a. Connect an ammeter in series between the slip rings and a battery of the specified voltage.	a. Field current draw should be approximately 2.5 amps. No reading on the ammeter indicates an open circuit. A higher than specified reading indicates a short circuit while a lower than specified reading indicates excessive resistance.
b. Connect one ammeter lead to one slip ring. Connect ground lead to the other slip ring.	b. Ammeter reading: ________

Caution: Do not connect both leads to the same slip ring. Damage to the ammeter will result.

Exercise 4

Reassemble the alternator.

	PROCEDURE		IMPORTANT INFORMATION
1.	Position the stator on the diode end housing.	1.	Make sure that all of the diodes, connections, stator leads, and condenser leads (internally installed, if used) will not interfere with the rotor fans.
2.	Position the rotor and drive end housing assembly on the diode end housing.	2.	
3.	Align the thru bolt holes through the drive end housing, stator and diode housing.	3.	
4.	Compress stator and both end housings together by hand.	4.	
5.	Install the thru bolts, washers, and nuts.	5.	
6.	Install the insulated brush, lock-washers, nylon washer, and terminal screw.	6.	
7.	Install the ground brush and attaching screw.	7.	
8.	Rotate the pulley.	8.	By hand and slowly. This is to be sure that the rotor fans do not hit the diode and stator connections.
9.	Have the instructor check your project.	9.	Instructor's Initials: ________

Exercise 5

Test the AC charging system.

PROCEDURE	IMPORTANT INFORMATION
1. Test the AC charging system assigned to you by the instructor.	1.
2. Have the instructor check your project.	2. Instructor's Initials: ________

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Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR4733
10

BATTERY AND MAGNETO IGNITION SYSTEMS

8-

OBJECTIVE

After completing this study guide/worksheet and your classroom instructio you will be able to test and isolate malfunctions of vehicle ignition system components by using special test equipment.

EQUIPMENT

	Basis of Issue
Operational Engine Trainers	1/2 students
Oscilloscope	1/2 students
Mechanic's Toolkit	1/2 students

INTRODUCTION

The study guide portion of this lesson contains information relative to the description, purpose, principle of operation, and operating instructions of the engine ignition analyzer oscilloscope. The worksheet portion contains procedures for the use and operation of the oscilloscope for testing the ignition system components.

OPR: TSDT
DISTRIBUTION: X
TSDT - 550; TSOC - 2

Designed for ATC Course Use Only

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OPERATION AND MAINTENANCE INSTRUCTIONS

WITH

PARTS BREAKDOWN

ENGINE IGNITION ANALYZER OSCILLOSCOPE

MODEL NO.
SS-5

FSN
4910-679-0898

SUN ELECTRIC CORPORATION

DAAG-11-67-C-0231

6060-359

298

1 NOVEMBER 1966

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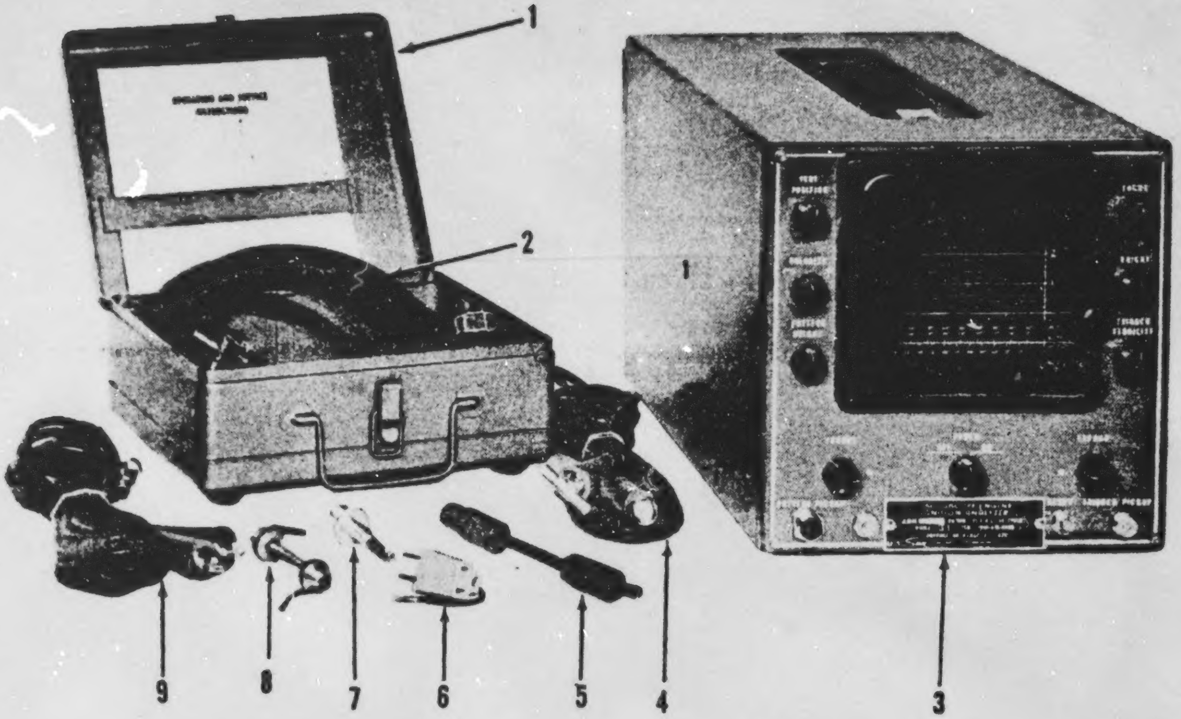
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Figure 1-1. Portable Engine Ignition Analyzer Oscilloscope Model No. SS-5

SECTION I

1-1. INTRODUCTION

1-2. This manual contains operation and maintenance instructions and a repair parts list for the Portable Engine Ignition Analyzer Oscilloscope, Sun Electric Corporation Model No. SS-5. This equipment will be referred to throughout this manual as the oscilloscope. (See figure 1-1).

1-3. Also included in this manual is a brief explanation of the oscilloscope principle of operation, waveform or portrayal interpretation and ignition tests and troubleshooting procedures.

1-4. DESCRIPTION AND PURPOSE

1-5. The oscilloscope, including the accessory kit, (see figure 1-1) is a self-contained unit requiring only external electrical power for operation. The oscilloscope operates on a power source of 115 volts, 60 cycle, single phase current.

1-6. The oscilloscope is designed to display in a graph-like picture, the operating events of spark ignition systems used on military, automotive and outboard marine engines. The accessory kit contains essential engine adapters for waterproof ignition systems.

1-7. OSCILLOSCOPE PRINCIPLE OF OPERATION

1-8. The oscilloscope screen may be compared to a graph as illustrated in figure 1-2. The vertical line represents voltage while the horizontal line represents time. Since the oscilloscope waveforms represent voltage in relation to time, the oscilloscope is especially useful when measuring a changing voltage.

1-9. Figure 1-2 depicts a constantly changing voltage during a period of one second, divided into quarters. From a starting point on the zero line, voltage increases steadily until it reaches its maximum positive value of +2 volts at time T_1. From this point the voltage decreases steadily to T_3 its maximum negative value of -2 volts. During the last quarter of a second the voltage begins to rise again until it reaches 0 volts at time T_4.

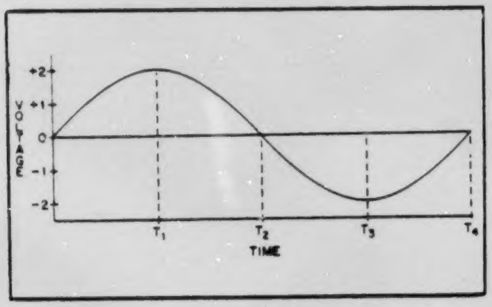


Figure 1-2. Voltage Measurement in Relation to Time

1-10. While viewing figure 1-2 you will note that all vertical movement of the trace (waveform) represents a voltage of one polarity when the trace is above the zero line, and of the opposite polarity below the zero line. Therefore, an oscillating waveform above and below the zero line, represents AC voltage.

1-11. Horizontal movement of the trace represents time. However, when the oscilloscope is used for testing ignition systems, time is not measured in seconds or minutes but in degrees of distributor rotation. For example: when testing an ignition system of a six cylinder engine, the system will cycle six times for every one revolution of the distributor. Dividing six into 360 degrees equals 60 degrees of distributor rotation for every one ignition cycle.

1-12. If the oscilloscope trace is adjusted so that one complete ignition cycle starts at 60 degrees, and ends at zero degrees on the dwell scale of the oscilloscope screen, any portion of the waveform can be accurately measured in degrees of distributor rotation.

1-13. WAVEFORM INTERPRETATION

1-14. Correct and accurate interpretation of oscilloscope waveforms is essential to proper ignition system analysis. Waveforms, either primary or secondary, depict ignition events as they occur in the engine. Malfunctions in an ignition system or defective components will distort these waveforms, thus indicating a problem. The location and shape of the distortion determines the type of problem and its probable location.

1-15. PRIMARY WAVEFORMS

1-16. Since the application of this oscilloscope provides mostly primary waveforms, this waveform is examined first. The primary waveform consists of three sections: THE FIRING SECTION, THE INTERMEDIATE SECTION, and the DWELL SECTION. (See figure 1-3).

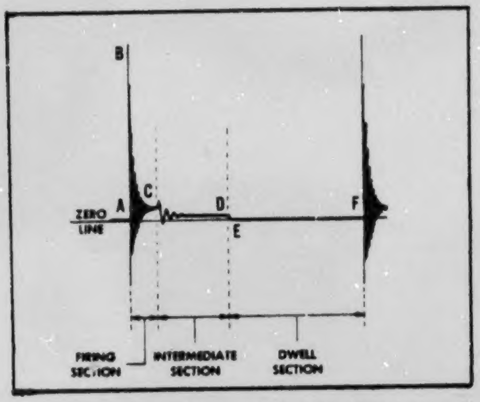


Figure 1-3. Basic Primary Waveform

1-17. FIRING SECTION

a. The Firing Section is so called because it is during this period that the actual firing of the spark plug takes place. This section displays a series of rapid oscillations that take place in the ignition primary circuit during the actual firing of a spark plug. Point A represents the instant at which the breaker points separate. Point B indicates the actual firing point of the spark plug and rotor gaps. Line AB is referred to as the firing line.

b. The vertical rise from A to B, and the diminishing oscillations that follow, represent the repeated charging and discharging of the condenser while the spark plug is firing. As the spark bridges the spark plug and rotor gaps and energy is drained from the coil, the amplitude, or height, of these oscillations diminishes until the spark is extinguished, as indicated at point C. Distortion in this section indicates; excessively high resistance in the secondary circuit, badly fouled spark plugs, or arcing of the points upon opening. The negative peak of the firing line may also be affected,

1-18. INTERMEDIATE SECTION

a. The Intermediate Section is seen as a series of gradually diminishing oscillations that represent the energy remaining in the coil after the spark is extinguished. This remaining energy dissipates itself as an oscillating current that gradually decreases until the contact points close at point D. Distortion in this section will be in the form of missing oscillations, which indicates a defective coil, condenser, or improper Dwell.

1-19. DWELL SECTION

a. The Dwell Section begins when the distributor contact points close at point D. The point close signal can be observed as a faint downward line from point D to point E. The Dwell Section is represented by the horizontal line which extends from point E to the point F. It is during this period that the points remain closed, and current flows in the primary circuit. Distortion in this section will be in the point close signal and indicates an adverse condition of the breaker points. The distortion may take the shape of a retrace, or a slight break in the point close signal.

1-20. SECONDARY WAVEFORMS

1-21. The secondary waveform, though somewhat different in shape, is a direct reflection of the primary waveform. (See figure 1-4). The secondary waveform consists of the same three sections as the primary, that is, the Firing Section, Intermediate Section, and the Dwell Section.

1-22. FIRING SECTION

a. The Firing Section of the secondary waveform is composed of only two lines. The first is the Firing Line, a vertical line that indicates the voltage required to overcome the spark plug and rotor gaps.

The second is the Spark Line, a horizontal line that indicates the voltage required to maintain the spark. Point A represents the instant at which the breaker points separate. The resulting high voltage is displayed in the waveform by the vertical line from A to B. Point B represents firing of the spark plug and rotor gap, and sometimes is referred to as the "ionization point."

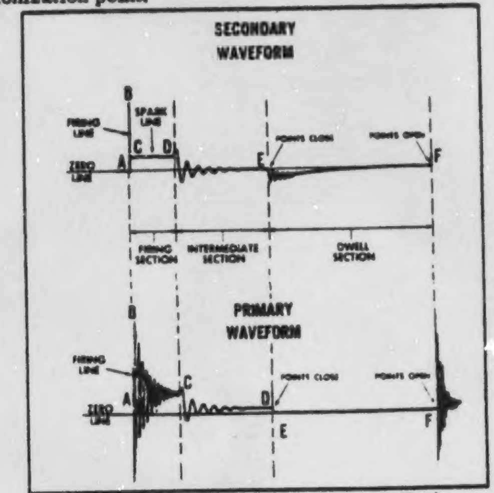


Figure 1-4. Secondary Waveform With Primary Waveform Comparison

b. After the spark plug fires there is a sharp drop in secondary voltage to point C. As the spark continues to bridge the gap, the spark voltage remains at a fairly low, but constant value until the spark extinguishes at point D. Distortion in this section indicates, excessively high resistance in the secondary circuit, badly fouled spark plugs, or arcing of the contact points on opening.

1-23. INTERMEDIATE SECTION

a. The Intermediate Section, which immediately follows the Firing Section, is seen as a series of gradually diminishing oscillations that represent the energy remaining in the coil after the spark is extinguished. This energy dissipates itself as an oscillating current that gradually decreases as it approaches point E. This oscillation results from the combined effects of the coil and condenser in dissipating this energy. Distortion in the Intermediate Section will be in the form of missing oscillations, which indicates defective coil, condenser, or improper Dwell.

1-24. DWELL SECTION

a. The Dwell Section represents that period of time during the ignition cycle, when the breaker points are closed. The Dwell Section begins at point E when the distributor contact points close. Closing the points causes a short downward line followed by a series of small, rapidly diminishing oscillations. The Dwell Section continues until the points open at the beginning of the next firing cycle (Point F). Distortion in this section indicates an adverse point condition,

SECTION II

2-1. OPERATING INSTRUCTIONS

2-2. Waterproof Ignition Systems

2-3. This section covers operation of the oscilloscope, when used on waterproof ignition systems. Some of the controls are preset and need not be adjusted each time the unit is used. Others are adjusted according to the operator's preference, or as required by the particular tests. No special safety precautions need be observed while operating this unit. However, it should be treated with the normal care and consideration given to any piece of electronic equipment. Avoid rough or abusive handling.

2-4. OPERATING PROCEDURE

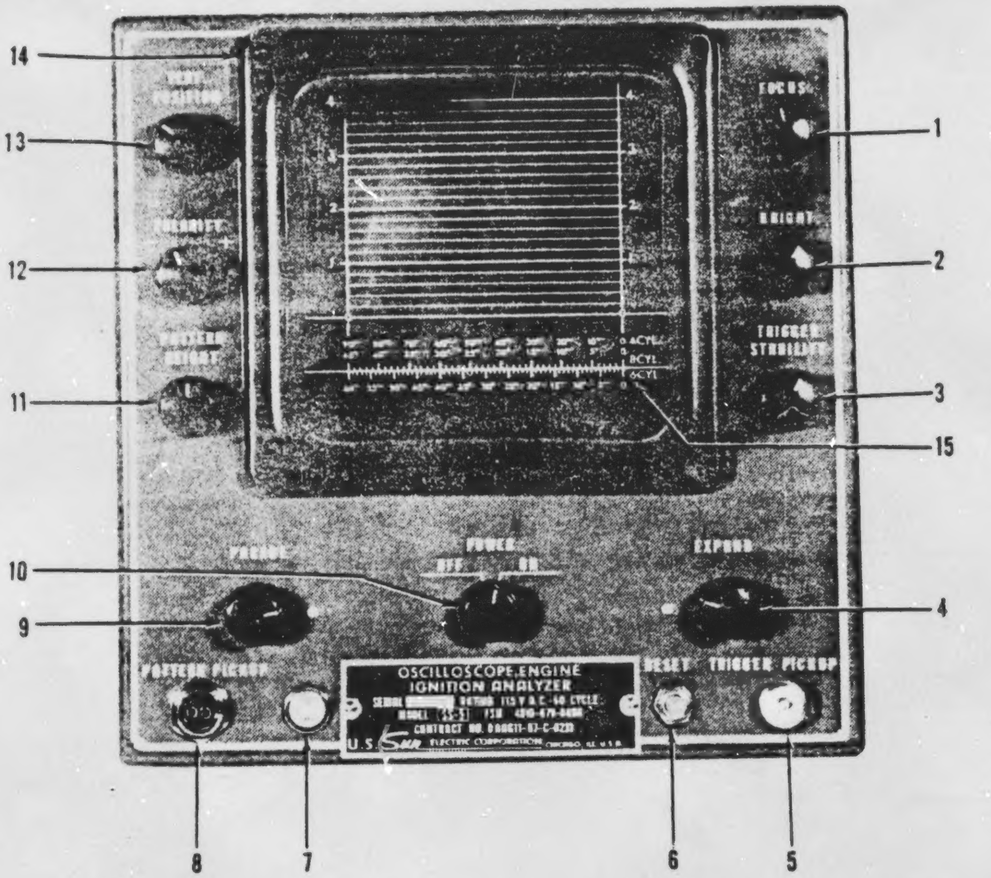
2-5. For location and identification of all controls, refer to figure 2-1.

a. Attach power cord (2, figure 1-1) to the rear of the oscilloscope case. Insert other end of power cord into a 115v ac power supply.

b. Set power switch (10, figure 2-1) to ON. When the power switch is in the ON position the pilot lamp (7, figure 2-1) should light.

NOTE

If the pilot lamp fails to light inspect ac power cord connections and proper voltage power supply. Press circuit breaker RESET button (6, figure 2-1).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FOCUS
BRIGHT
TRIGGER STABILITY
PARADE
POWER
OFF
ON
EXPAND
PATTERN PICKUP
RESET
TRIGGER PICKUP
OSCILLOSCOPE ENGINE
IGNITION ANALYZER
U.S.

1. Focus Control
2. Brightness Control
3. Trigger Stability Control
4. Expand Control
5. Trigger Pickup Connector
6. Reset Button
7. Pilot Light
8. Pattern Pickup Connector
9. Parade Control
10. Power Switch
11. Pattern Height Control
12. Polarity Switch
13. Vertical Position Control
14. Bezel Assembly

Figure 2-1. Oscilloscope Control Panel

c. Rotate expand control knob (4, figure 2-1) until the index line and dot are in alignment. This knob adjusts the length or horizontal gain of the waveform and permits close examination of each cylinder.

d. Align parade control knob (9, figure 2-1) as outlined in step c. The parade knob adjusts horizontal position of the waveform and permits parading of individual cylinders across the screen, for closer examination.

e. Rotate pattern height knob (11, figure 2-1) to an upright position. The waveform height or vertical gain is controlled and adjusted with this knob.

f. Set polarity switch (12, figure 2-1) to match polarity of the vehicle battery ground terminal. The polarity switch changes polarity of the waveform.

g. Rotate vertical position knob (13, figure 2-1) to an upright position. The vertical position of the waveform is controlled and adjusted with this knob.

h. Adjust the trigger stability knob (3, figure 2-1) as outlined in step g. This control eliminates horizontal movement or roll of the waveform caused by improper synchronization of the oscilloscope with the engine.

i. Adjust brightness control knob (2, figure 2-1) as outlined in step g. Brilliance or intensity of the waveform is adjusted by this knob.

j. Adjust focus control knob (1, figure 2-1) as outlined in step g. The focus knob focuses the waveform for maximum clarity and shall be adjusted whenever the brightness control knob (2, figure 2-1) is changed.

2-6. OSCILLOSCOPE CONNECTIONS TO ENGINE WATERPROOF IGNITION SYSTEMS

2-7. **Connections.** The following connections will provide only a Primary Display Waveform.

a. Remove adapter plug from distributor cap.

b. Install primary pick-up adapter, (7, figure 1-1).

c. Connect red lead of the pattern pick-up to the primary pick-up adapter.

d. Connect black pattern pick-up lead (9, figure 1-1) to a suitable engine ground.

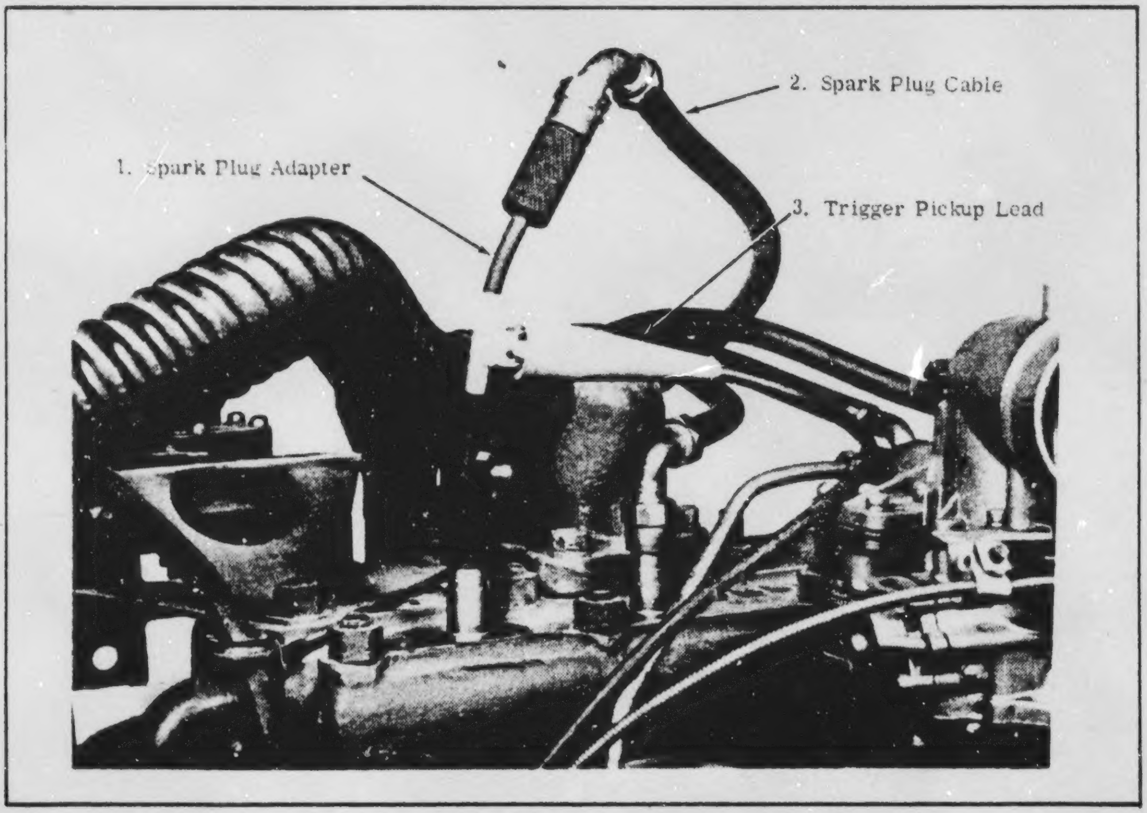

Figure 2-2. Trigger Pickup Lead and Adapter Connections

e. Remove spark plug cable from the spark plug of the timing cylinder.

f. Attach trigger adapter, (5, figure 1-1) to timing cylinder spark plug.

g. Connect timing cylinder spark plug cable to trigger adapter.

h. Connect trigger pick-up lead (4, figure 1-1) of the oscilloscope to the trigger pick-up adapter as shown in figure 2-2.

i. Set polarity switch (12, figure 2-1) to match the vehicle battery ground polarity.

j. Set the trace on the zero line, using the vertical position control.

k. Start engine and adjust idle speed if necessary.

l. Observe waveform, and adjust the spark line height to line 1, using the pattern height control. Adjust the remaining controls for the desired position, clarity and brightness. If waveform appears to be unstable, or is moving horizontally across the screen, adjust the trigger stabilization control (3, figure 2-1) until the waveform is steady.

m. Stop engine.

NOTE

If the waveform cannot be stabilized with the trigger stabilization control it is possible that the trigger cylinder spark plug is badly fouled. In this event stop the engine and install the trigger adapter on the spark plug for the alternate timing cylinder. The alternate timing cylinder can be determined by dividing the firing order in half, and arranging the two halves in the form of a fraction. The timing cylinder and its alternate cylinder then will be arranged one above the other. For example, if No. one cylinder is used to time a six cylinder engine whose firing order is 1-5-3-6-2-4, the alternate timing cylinder is No. six. Arranged as a fraction, the firing order becomes:

$$\frac{1\text{-}5\text{-}3}{6\text{-}2\text{-}4}$$

which shows that cylinder Nos. one and six are the timing cylinders.

3-1. TESTING WATERPROOF IGNITION SYSTEMS

3-2. Cranking Coil Output Test. This test reveals the availability of voltage required to fire the rotor and spark plug gaps. Proceed as follows:

a. Disconnect one spark plug wire. Isolate the wire so that a spark cannot jump to ground.

b. Back idle speed screw out far enough to allow the throttle plate to close completely, thus preventing the engine from starting.

c. Crank engine only long enough to note the coil output. Height of firing line should increase approximately to line 1. (See figure 3-1).

d. After test, reconnect spark plug wire.

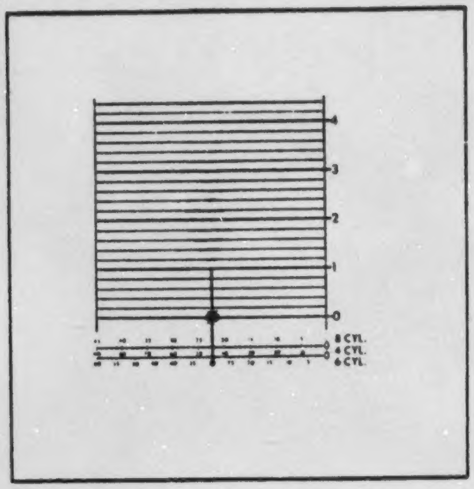

Figure 3-1. Coil Output Waveform Engine Cranking

3-3. Results and Indications. Low coil output: Low battery, defective ignition primary circuit, failure of resistor by-pass circuit, insufficient dwell, excessive distributor resistance, defective coil or condenser.

3-4. IGNITION SYSTEM POLARITY TEST

3-5. Incorrect ignition system polarity can result in 20 to 40 per cent higher voltage required to fire spark plugs. Proceed as follows:

a. Set polarity switch (12, figure 2-1) to correspond with vehicle battery ground polarity.

b. Start engine and run at idle speed.

c. Primary waveform should appear as illustrated in figure 3-2.

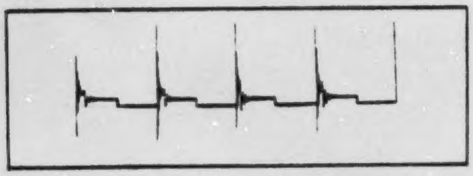

Figure 3-2. Primary Display Waveform

3-6. Results and indications. Inverted waveform: vehicle battery polarity reversed. No waveform or straight line: improper coil or improper coil wire connections.

3-7. DWELL TEST

3-8. Dwell is the number of distributor degrees that the contact points remain closed during each ignition cycle. To perform the dwell test, proceed as follows:

a. Run engine at idle speed.

b. Expand waveform so one firing line is at each vertical line on the oscilloscope screen.

c. Lower waveform so that it touches the dwell scale at the bottom of the oscilloscope screen.

d. The point close signal indicates the degrees of dwell. Be sure to read the proper scale.

3-9. Results and Indications. Dwell reading within the specification: ignition points are operating normally and are spaced properly. Dwell reading not within specification: improper point spacing, wrong point assembly, point rubbing block defective, point rubbing block misaligned, worn distributor cam.

3-10. DWELL VARIATION

3-11. Dwell variation is determined by noting any dwell change as the engine is operated at different speeds. Excessive variation indicates a change in point opening that may result from shaft or bushing wear, or from the distributor plate shifting because of wear or looseness. To observe dwell variation note the following:

a. Distributor Dwell at idle speed.

b. Dwell indication at 1000 RPM. Dwell indication should not change more than 3 degrees on most vehicles. Refer to vehicle's specifications before condemning distributor.

NOTE

If the waveform moves horizontally on the screen when the engine speed increases, reposition it with parade control knob.

3-12. Results and Indications. Dwell variation within manufacturer's specified tolerance: distributor is in good mechanical condition. Dwell variation exceeds manufacturer's maximum specification: worn distributor shaft, worn bushing, or worn breaker plate.

3-13. CAM LOBE ACCURACY TEST

3-14. The accuracy of the ignition distributor cam determines the ignition timing relationship of all the cylinders. Should one or more of the distributor cam lobes be worn, the distributor shaft bent, or worn shaft or bushings, uneven timing of the cylinders will result. Proceed as follows:

a. Adjust engine speed to 1000 RPM.

b. Expand primary waveform as for the dwell test.

c. Starting with the first cylinder, parade the cylinders across the oscilloscope screen, checking the dwell of each one. Note any variation in dwell.

NOTE

The expand control knob may require adjustment during step c.

d. The number of degrees of variation in the dwell, or the point close signals, indicates the number of degrees of distributor cam lobe variation. This variation should not exceed 2 degrees.

e. Return waveform to zero line on screen.

3-15. SECONDARY CIRCUIT CONDITION TEST

3-16. Analysis of the firing line and spark line of the primary display waveform will reveal the presence of excess resistance in the secondary circuit. Excess resistance in this circuit absorbs some of the power necessary for proper ignition, thus resulting in poor engine performance. Proceed as follows:

a. Start engine and adjust speed to 1000 RPM.

b. Adjust parade and expand controls to obtain a primary display waveform.

c. Reverse the polarity switch.

d. Observe waveform for distortion in the firing section. (See figure 3-3). Expand and parade waveform for desired clarity of each cylinder.

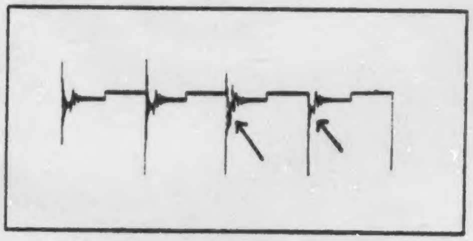

Figure 3-3 Firing Section Distortions

3-17. If distortion appears in the firing section, perform the following tests to determine the cause.

a. Stop engine and remove spark plug wire retaining nuts from the spark plugs of the cylinders showing distortion.

b. Start engine and adjust speed to 1000 RPM.

c. Remove each wire individually from the spark plug, and ground it.

d. Observe the waveform and refer to Results and Indications.

3-18. Results and Indications. Spark line appears normal after grounding spark plug wire: defective spark plug, or engine condition affecting spark plug. (See figure 3-4). Spark line remains distorted with spark plug wire grounded:

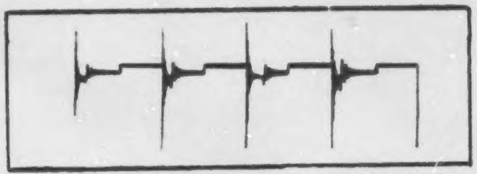

Figure 3-4. Normal Spark Line With Spark Plug Wire Grounded

a. On one or more cylinders: defective distributor cap towers, or individual spark plug wires. Ground the distributor cap tower with a suitable probe to determine if the cap or wire is defective.

b. On all cylinders: defective coil tower, coil wire, distributor cap towers, or rotor.

3-19. COIL AND CONDENSER TEST

a. Set polarity switch to match vehicle battery ground polarity.

3-20. The Intermediate Section, usually observed as a series of diminishing oscillations, represents the dissipation of the energy remaining in the coil after the spark plug has ceased firing. Ignition system trouble can be detected by noting the rate at which the oscillations diminish. Normally these oscillations diminish gradually. Proceed as follows:

a. Observe the Intermediate Section for gradually diminishing oscillations. If the intermediate section is incomplete, and dwell is normal, reduce engine speed to observe the complete intermediate section.

3-21. Results and Indications. Lack of oscillations in intermediate section: short in coil or leaky condenser. (See figure 3-5).

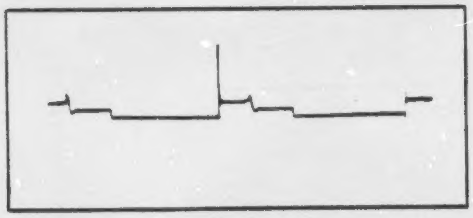

Figure 3-5. Shorted Coil Or Leaky Condenser

3-22. POINT CONDITION AND ACTION TEST

3-23. The Dwell Section begins when the distributor contact points close and extend to the instant at which the contact points open to fire the next cylinder. When analyzing this section of the waveform, the point close and the point open signals should be carefully observed. Observe the following:

a. Dwell section for point close and point open signals. (See figure 3-6, 3-7 and 3-8).

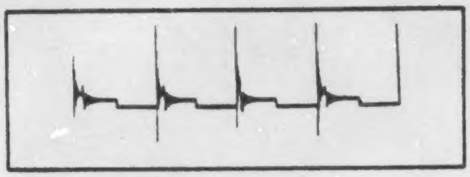

Figure 3-6. Distorted Point Close

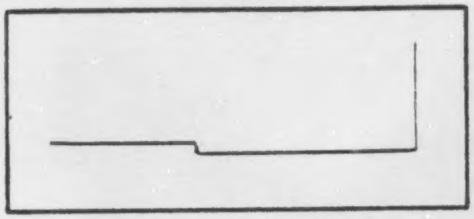

Figure 3-7. Point Close - Expanded

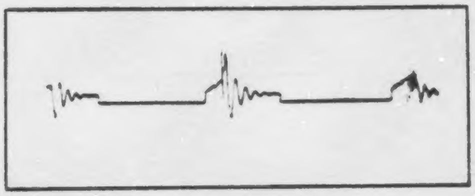

Figure 3-8. Distorted Point Open

b. Adjust pattern height control as desired for a clearer view of the point close signal. (See figure 3-6 and 3-7).

c. After test adjust firing line height to line 1.

3-24. Results and Indications.

a. Figures 3-6 and 3-7 depict burned or high resistance contact surfaces. Figure 3-8 shows the points arcing when opening. This condition results from pitted contact surfaces or a defective condenser.

3-25. SPARK PLUG FIRING VOLTAGE TEST

3-26. Spark plug firing voltage is the voltage required to overcome the rotor and spark plug gaps, and establish a spark across the spark plug electrodes. Temperature, fuel mixture, compression pressure and condition of the spark plugs and/or secondary circuit affect the required firing voltage. Proceed as follows:

a. Set parade and expand control knobs to obtain a PRIMARY DISPLAY waveform.

a. Stop engine and remove spark plug wire retaining nuts from spark plugs of the cylinders showing distortion.

b. Start engine and adjust speed to 1000 RPM.

c. Remove each wire individually from spark plug, and ground it.

d. Observe waveform. The upward peak should be approximately 1/2 the length of downward peak. (See figure 3-9). The spark line should be smooth, and slanted downward.

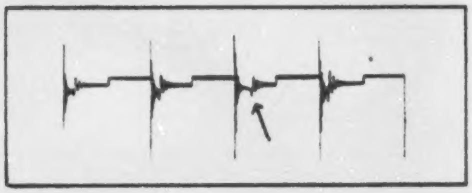

Figure 3-9. Firing Voltage

3-28. Results and Indications. Upward peak approximately 1/2 the length of downward peak when spark plug wire is grounded: worn spark plugs or engine condition affecting the spark plugs. Upward peak less than 1/2 of the downward peak, or if spark line slants upward when spark plug is grounded, on all cylinders: poor connection between coil and rotor or wide rotor gap.

Uneven Firing Voltage: worn spark plugs, broken spark plug wires, or cocked or worn distributor cap. Ground distributor cap tower to determine if cap or wire is defective. If waveform fails to meet step d, paragraph 3-27, problem is in the cap. If waveform passes step d, problem is in the wire.

3-29. MAXIMUM COIL OUTPUT TEST (Available Voltage).

3-30. Maximum Coil Output is a term used to describe the maximum secondary voltage that an ignition system is able to produce under a given operating condition. Because of its operating principle, an ignition coil will produce its maximum voltage whenever it attempts to fire an impossible gap, such as when a spark plug wire is removed from a spark plug and held away from ground. For this test, proceed as follows:

a. Set engine speed to approximately 2500.

b. Set polarity switch to match vehicle battery ground polarity.

c. Use insulated pliers to disconnect spark plug wire from spark plug. Hold wire away from ground.

d. Observe height of firing line. Height should increase by 1/3 upward, and by 1/2 downward.

e. Reduce engine speed to 1000 RPM.

3-31. Results and Indications. Insufficient Coil Output; excessive resistance in the primary circuit, low primary input voltage, defective coil, dwell less than specified or defective secondary insulation.

3-32. SECONDARY INSULATION TEST

3-33. When an ignition coil produces a surge of high voltage, as a result of the collapse of its magnetic field, the voltage is applied from the coil tower to the coil wire, distributor cap, rotor and the secondary wire, and finally to the spark plug to create the spark across its electrodes. It must be realized that insulation of all parts of the secondary circuit must be of high quality and in good condition to insure reliable ignition under all operating conditions. Proceed as follows:

a. Set polarity switch to match vehicle battery ground polarity.

b. With a spark plug wire removed as for the Maximum Coil Output test, observe downward peak of the waveform. For primary waveform it should be approximately 1/3 of the upward peak, and be consistent.

c. Reconnect spark plug wire and test remaining cylinders in the same manner.

3-34. Results and Indications. Short, intermittent or absent lower extent on one or more cylinders: insulation leakage in the distributor cap or spark plug wires. Short, intermittent or absent lower extent on all cylinders: insulation leakage in coil tower, rotor, coil wire or distributor cap.

SECTION IV

4-1. OSCILLOSCOPE CONNECTIONS TO ENGINE STANDARD IGNITION SYSTEM

4-2. Connections. The following connections, for standard ignition system differ somewhat from those listed in paragraph 2-7. The basic difference results in a secondary waveform. Also, by changing the trigger pick-up, a superimposed waveform can be obtained.

4-3. Secondary Display Waveform Connections

a. Connect red pattern pick-up lead (9, figure 1-1) to center of coil high tension lead as illustrated in figure 4-1.

b. Attach black pattern pick-up lead (9, figure 1-1) to a suitable engine ground.

c. Attach trigger pick-up lead (4, figure 1-1) to timing cylinder spark plug wire three to six inches from the distributor cap. (See figure 4-2).

NOTE

The trigger pick-up clip must be insulated from the high voltage spark. If arcing occurs between the wire and trigger pick-up clip, the spark plug for that cylinder will not fire.

d. Set polarity switch (12, figure 2-1) opposite or reversed position from the vehicle battery ground polarity.

e. Align the trace on the zero line by adjusting the vertical position control knob.

f. Start engine and adjust idle speed if necessary.

g. Adjust firing line height to line 1 by rotating the pattern height control knob.

h. Refer to paragraph 2-7, step l.

i. If the waveform appears unstable refer to the note following step m, paragraph 2-7.

4-4. Superimposed Waveform Connections

a. See paragraph 4-3, step a.

b. See paragraph 4-3, step b.

c. Connect trigger pick-up lead (4, figure 1-1) to center of coil high tension lead. (Refer to figure 4-3.

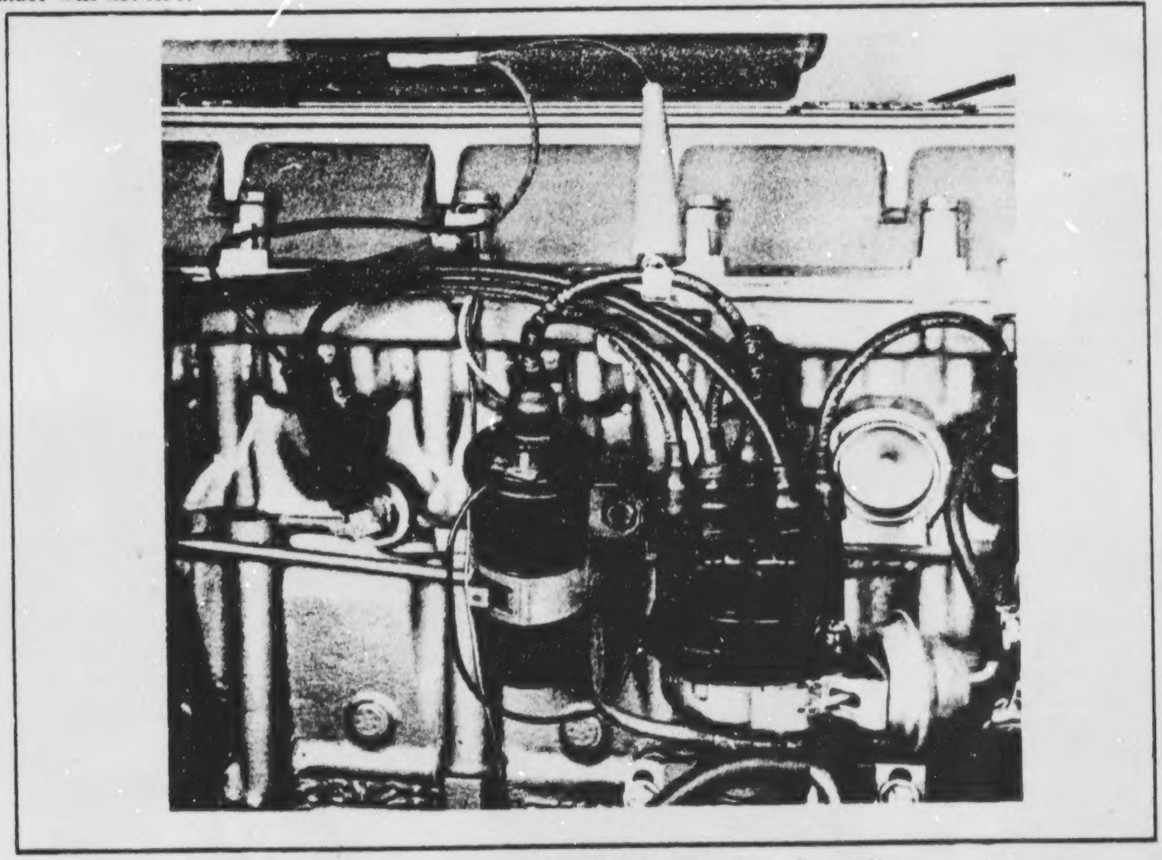

Figure 4-1. Secondary Display Waveform Connections

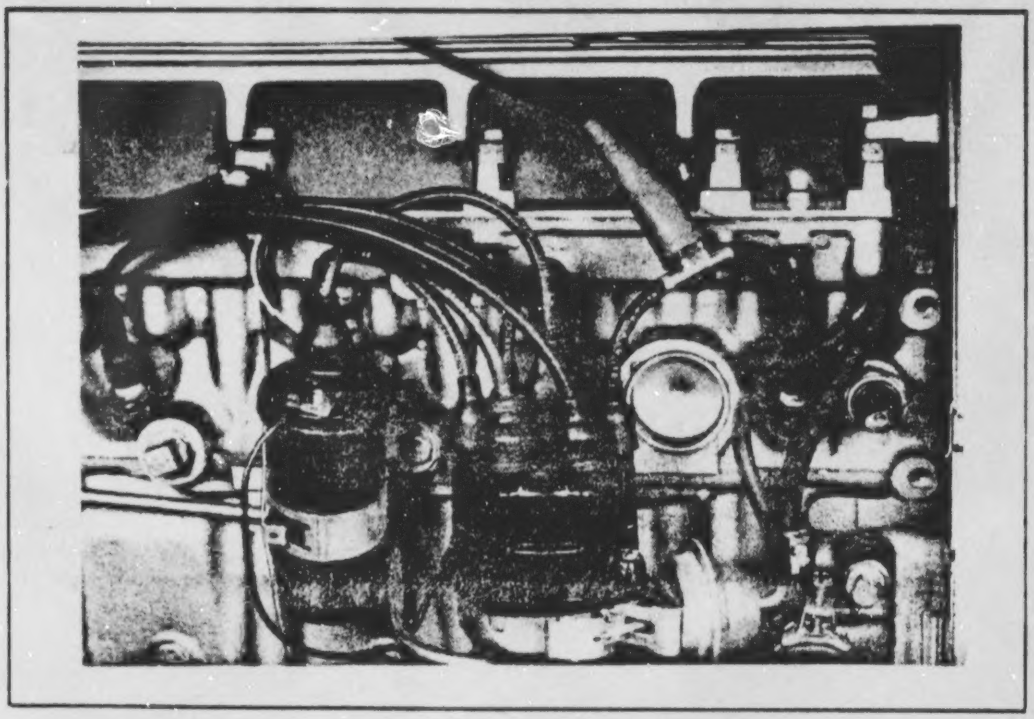

Figure 4-2. Trigger Pickup Connection

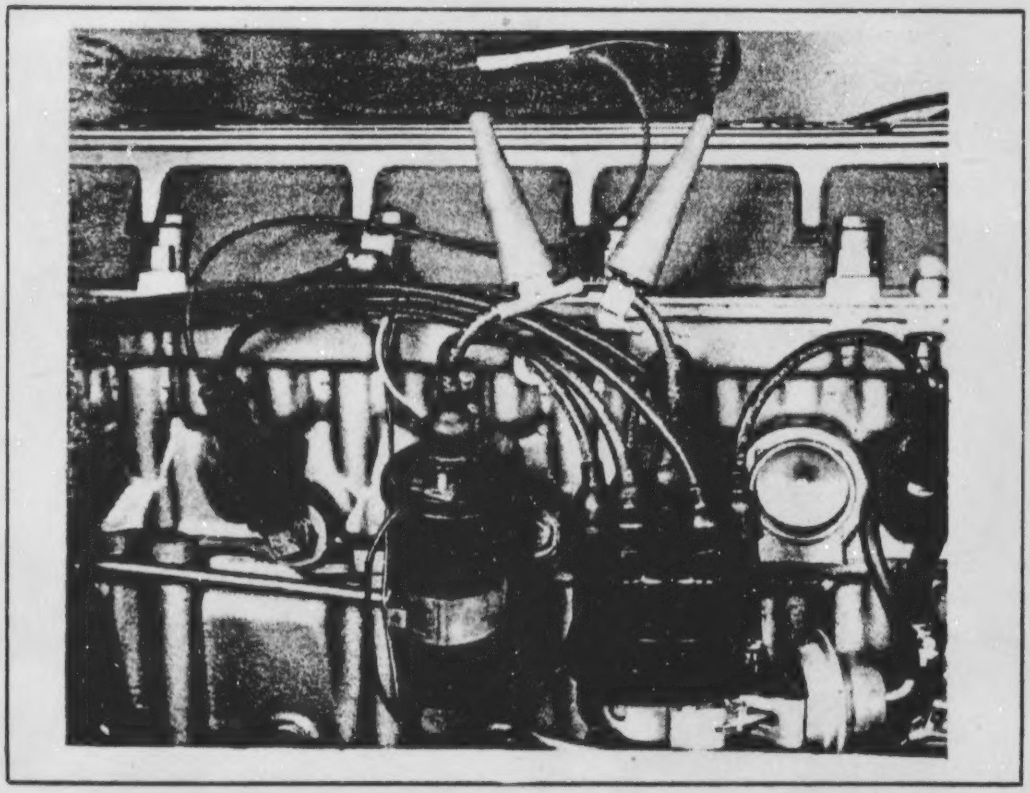

Figure 4-3. Superimposed Waveform Connections

NOTE

Trigger pick-up clip must be insulated from the high voltage spark. If arcing occurs between this wire and the trigger pick-up clip, the engine will not run properly.

d. Set polarity switch opposite vehicle battery ground polarity.

4-5. STANDARD IGNITION SYSTEM TESTS

4-5. This section outlines various ignition tests that can be made with the oscilloscope. These tests apply to the standard ignition systems and are made with a secondary display waveform unless it is stated otherwise.

4-7. COIL OUTPUT TEST - CRANKING

4-8. This test indicates the availability of voltage required to fire the rotor and spark plug gaps while the engine is being turned over. This test is made as follows:

a. Remove coil wire from distributor cap and isolate the wire so that a spark cannot jump to ground.

b. Crank the engine, and note the coil output. (See figure 4-4).

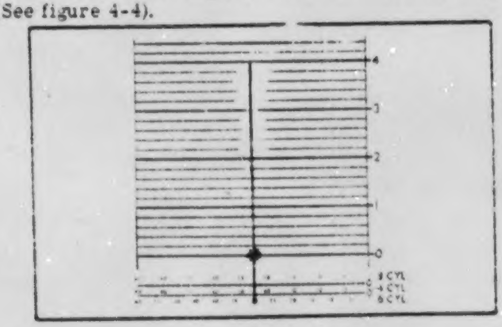

Figure 4-4. Coil Output - Cranking

c. Height of the waveform should extend to the top of the screen.

d. Replace coil wire into distributor.

4-9. Results and Indications. Low coil output: low battery, defective ignition primary circuit, failure of ignition resistor by-pass circuit, insufficient dwell, excessive distributor resistance, defective coil or condenser.

4-10. IGNITION SYSTEM POLARITY TEST

4-11. Incorrect ignition system polarity can result in 20 to 40 per cent higher voltage required to fire spark plugs. Check system polarity as follows:

a. Set oscilloscope polarity switch opposite the vehicle battery ground polarity.

b. Start engine and run at idle speed.

c. Secondary waveform should appear as shown in figure 4-5).

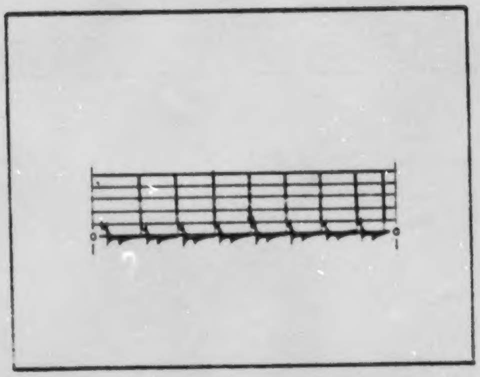

Figure 4-5. Normal Secondary Display Waveform

4-12. Results and Indications. Inverted waveform: vehicle battery polarity reversed, ignition coil improperly connected, incorrect coil for the vehicle.

4-13. DWELL TEST

4-14. The dwell test procedure is as follows:

a. Run engine at idle speed.

b. Transfer trigger pick-up lead to coil wire for the superimposed waveform.

c. Adjust length of waveform so it starts and ends at the vertical lines on the oscilloscope screen.

d. Lower waveform so it touches dwell scale at the bottom of the oscilloscope screen.

e. The point close signal indicates degrees of dwell. Be sure to read the proper scale. (See figure 4-6).

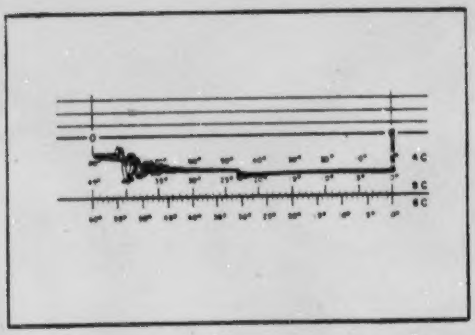

Figure 4-6. Point Close

4-15. Results and Indications. Dwell reading within the specification; ignition points are operating normally and are spaced properly. Dwell reading not within specification: improper point spacing, wrong point assembly, point rubbing block defective, point rubbing block misaligned, worn distributor cam.

4-16. DWELL VARIATION TEST

4-17. Dwell variation is determined by noting any dwell change as the engine is operated at different speeds. Excessive variation indicates a change in point opening that may result from shaft or bushing wear, or from the distributor plate shifting because of wear or looseness. Proceed as follows:

a. Use the superimposed waveform for this test.

b. Note distributor dwell at idle speed.

NOTE

If the waveform moves horizontally on the screen when the engine speed increases, reposition it using the parade control.

c. Note dwell reading at 1000 RPM. Dwell reading should not change more than 3 degrees on most vehicles. Refer to vehicle's specifications before condemning distributor.

4-18. Results and Indications. Dwell variation within manufacturer's specified tolerance: distributor is in good mechanical condition. Dwell variation exceeds manufacturer's maximum specification: worn distributor shaft, worn bushing, worn breaker plate.

4-19. CAM LOBE ACCURACY TEST

4-20. Accuracy of the ignition distributor cam determines ignition timing relationship of all cylinders. Should one or more of the distributor cam lobes become worn, or the distributor shaft be bent, uneven timing of the cylinders will result. Proceed as follows:

a. Set engine speed to 1000 RPM.

b. Superimpose waveform.

c. Adjust length of waveform so it starts and ends at the vertical lines on the oscilloscope screen, as in the dwell test.

d. Note variation in the point close signals.

4-21. Results and Indications. The number of degrees variation in dwell, or point close signals, indicates the number of degrees of distributor cam lobe variation. This variation should not exceed 2 degrees.

4-22. SECONDARY CIRCUIT CONDITION TEST

4-23. Analysis of the firing line and spark line of the secondary waveform will reveal the presence of excess resistance in the secondary circuit. Excess resistance in this circuit absorbs some of the power necessary for proper ignition, thus resulting in poor engine performance. Proceed as follows:

NOTE

Some resistance is desirable in standard ignition systems to reduce ignition interference with radio and television reception. This resistance is known as ignition suppression.

a. Use the secondary display waveform.

b. Replace trigger pick-up timing cylinder spark plug wire.

c. Start engine and adjust speed to 1000 RPM.

d. Adjust firing line height to line 1, using pattern height control.

e. Observe firing lines and spark lines for distortion. Expand and parade waveform as desired for closer observation.

4-24. If distortion appears in the firing section, perform the following detailed test to determine the cause.

a. Remove the wire from the spark plug of the cylinder showing distortion, and ground it.

b. Observe the waveform: refer to Results and Indications.

4-25. Results and Indications. (See figure 4-7). Spark line appears normal after grounding spark plug wire: defective spark plug, or engine condition affecting spark plug. Spark line remains distorted with spark plug wire grounded:

a. On one or more cylinders: defective distributor cap towers, or individual spark plug wires. Ground the distributor cap tower with a suitable probe to determine if the cap or wire is defective.

b. On all cylinders: defective coil tower, coil wire, distributor cap towers, or rotor.

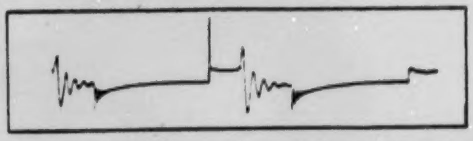

Figure 4-7. Normal Secondary Waveform Expanded

4-26. COIL AND CONDENSER TEST

4-27. The Intermediate Section, usually observed as a series of diminishing oscillations, represents dissipation of energy remaining in the coil after the spark plug has ceased firing. Ignition system trouble can be detected by noting the rate at which the oscillations diminish. Normally these oscillations diminish gradually. Observe the following:

a. Intermediate Section for gradually diminishing oscillations. If the intermediate section is incomplete, and dwell is normal, reduce engine speed to observe the complete intermediate waveform. Expand and parade waveform as desired for closer observation.

4-28. Results and Indications. Lack of oscillations in intermediate section: short in coil, leaky condenser or poor coil wire connections.

b. Reverse polarity switch.

c. Observe firing line and spark line of all cylinders for height and uniformity.

3-27. If abnormal firing lines are observed, proceed with the following tests to determine the cause.

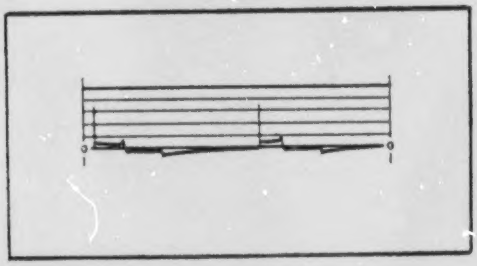

Figure 4-8. Missing Oscillations

Defective Intermediate Section

4-29. POINT CONDITION AND ACTION TEST

4-30. The Dwell Section begins when the distributor contacts close and extends to the instant at which the contacts open to fire the next cylinder. When analyzing this section of the waveform, the point close and the point open signals should be carefully observed. Proceed as follows:

a. Observe Dwell Section for point close and point open signals.

b. Expand and parade waveform as desired for closer observation.

4-31. Results and Indications.

a. Figure 4-9 depicts burned or high resistance contact surfaces. Figure 4-10 shows the points arcing when opening. This condition results from pitted contact surfaces or a defective condenser.

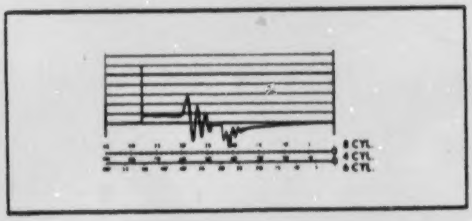

Figure 4-9. Point Close

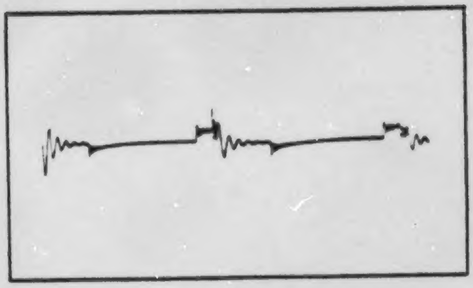

Figure 4-10. Point Open

4-32. SPARK PLUG FIRING VOLTAGE TEST

4-33. Spark Plug Firing Voltage is the voltage required to overcome the rotor and spark plug gaps, and establish a spark across the spark plug electrodes. Temperature, fuel mixture, compression pressure and condition of the spark plugs and/or secondary circuit affect the required firing voltage. Proceed as follows:

a. Use the secondary display waveform for this test.

b. Set the polarity switch opposite the vehicle battery ground polarity.

c. Run engine at 1000 RPM.

d. Observe firing line and spark line of all cylinders for height and uniformity. A slight variation in the secondary firing lines is normal.

NOTE

If unusually high or low firing lines are observed, proceed with the following detailed tests to determine the cause.

1. Expand the waveform as desired, and locate the defective cylinder.

2. Remove each wire individually from the spark plug, and ground it.

3. Observe the waveform. The firing line should come below line 1, and the spark line should be smooth and nearly flat.

4. Refer to Results and Indications.

4-34. Results and Indications. If a normal waveform appears when the spark plug wire is grounded; worn spark plugs, or engine condition affecting the firing voltage. If waveform remains distorted when the spark plug wire is grounded:

a. One cylinder or more: defective spark plug wire, distributor cap tower, or misaligned distributor cap. Ground distributor cap towers to determine if distributor cap, or spark plug wire is defective.

4-35. MAXIMUM COIL OUTPUT TEST (Available Voltage)

4-36. Maximum Coil Output is a term used to describe the maximum secondary voltage that an ignition system is able to produce under a given operating condition. Because of its operating principle, an ignition coil will produce its maximum voltage whenever it attempts to fire an impossible gap, such as when a spark plug wire is removed from a spark plug and held away from ground. Proceed as follows:

a. Use the secondary display waveform for this test.

b. Set polarity switch opposite the vehicle battery ground polarity.

c. Set engine speed to 2500 RPM.

d. Using insulated pliers disconnect spark plug wire from a spark plug. Hold the wire away from ground.

e. Observe height of firing line. Height of firing line should increase approximately to line 3, downward extent should be 1/2 of the upward extent.

f. Reduce engine speed to 1000 RPM.

4-37. Results and Indications. Insufficient Coil Output: excessive resistance in the primary circuit, low primary input voltage, defective coil, dwell less than specified or defective secondary insulation.

4-38. SECONDARY INSULATION TEST

4-39. When an ignition coil produces a surge of high voltage, as a result of the collapse of its magnetic field, the voltage is applied from the coil tower to the coil wire, distributor cap, rotor and the secondary wire, and finally to the spark plug to create a spark across its electrodes. It must be realized that the insulation of all parts of the secondary circuit must be of high quality and in good condition to insure reliable ignition under all operating conditions. Proceed as follows:

a. Use the secondary display waveform for this test.

b. Set the polarity switch opposite the vehicle battery ground polarity.

c. Run engine at 1000 RPM.

d. With spark plug wire removed as for the Maximum Coil Output test, observe downward peak of the waveform. The downward peak should be 1/2 or more of the upward peak, and be consistent.

e. Reconnect spark plug wire and test remaining cylinders in the same manner.

4-40. Results and Indications. Short, intermittent or absent lower extent:

a. On one or more cylinders: insulation leakage in the distributor cap or spark plug wires.

b. On all cylinders: insulation leakage in coil tower, rotor, coil wire or distributor cap.

4-41. SPARK PLUGS UNDER LOAD TEST

4-42. When a load is applied to an engine, the required firing voltage rises. This rise will be slight and uniform if the plugs are in good condition, and properly gapped. However, if any unusual firing characteristics are observed while the engine is operating under a load, an abnormal spark plug condition may exist. Pay particular attention to the firing voltages that are considerably higher or lower than the firing requirements of the other cylinders of the engine. Proceed as follows:

a. Set polarity switch opposite the vehicle battery ground polarity.

b. Momentarily load engine by "snap acceleration."

c. Observe rise of the firing voltages. The rise should be moderate and uniform.

4-43. Results and Indications. One or more firing lines higher than others: wide plug gap, open spark plug resistor or badly deteriorated electrodes. One or more firing lines lower than others: spark plug fouling, flashover or cracked insulator.

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SECTION V

5-1. MAINTENANCE

5-2. The oscilloscope requires no periodic maintenance or service.

5-3. The design of the oscilloscope is such that assembly and disassembly instructions are not required except for the removal of the cathode ray tube.

CAUTION

When removing the cathode ray tube, rubber gloves and safety glasses should be worn. When handling the cathode ray tube, extreme care should be taken to hold the tube by the face end rather than the neck section.

5-4. To remove the cathode ray tube, proceed as follows:

a. Loosen two screws holding clamp to neck of cathode tube.

NOTE

It is not necessary to completely remove the clamp.

b. Disconnect base socket from neck end of tube.

c. Remove four screws from bezel assembly (14, figure 2-1).

d. Remove four screws from dwell scale (15, figure 2-1).

e. Grasp the face of the cathode ray tube and gently pull the tube from the protective metal cone.

f. Reassembly of all components as well as the cathode ray tube is essentially in the reverse order of disassembly.

SECTION VI

6-1. RECOMMENDED PARTS LIST

6-2. This parts list includes those items used in the oscilloscope; Model SS-5, which are considered by the manufacturer as replaceable.

6-3. INSTRUCTIONS FOR REQUISITIONING PARTS NOT IDENTIFIED BY FSN

6-4. When requisitioning parts not identified by Federal Stock Number, it is mandatory that the following information be furnished the supply officer:

a. Manufacturer's Federal Supply code number. (82386)

b. Manufacturer's part number exactly as listed herein.

c. Nomenclature exactly as listed herein, including dimensions if necessary.

d. Manufacturer's model number (end item).

e. Manufacturer's serial number (end item).

f. Any other information such as type, frame number, and electrical characteristics, if applicable.

g. If DD Form 1348 is used, fill in all blocks except 4, 5, 6 and Remarks Field in accordance with AR 725-50. Complete form as follows:

1. In blocks 4, 5 and 6, list manufacturer's Federal Supply code number (82386) followed by a colon and manufacturer's part number for the repair part.
2. Complete Remarks Field as follows:

Noun:	(nomenclature of repair part).
For:	(FSN of end item).
Mfr:	(of end item).
Model:	(of end item).
Serial:	(of end item).

(Any other pertinent information such as frame number, type, dimensions, etc).

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RECOMMENDED REPLACEABLE PARTS LIST

Fig. and Index No.	Part Number	Description and Vendor Codes	Ref. Des.	Quantity Per Unit
1-1-1	710-265	BOX, ACCESSORIES		1
1-1-2	2-105-73	POWER CABLE, AC		1
1-1-3	1243-100	PLATE, IDENTIFICATION		1
1-1-4	6005-083	LEAD ASSY, TRIGGER PICK-UP		1
1-1-5	2436-010	ADAPTER, SPARK PLUG		1
1-1-6	825-6	ADAPTER, AC PLUG		1
1-1-7	2546-1	ADAPTER, PRIMARY CIRCUIT		1
1-1-8	2546-002	ADAPTER, SECONDARY CIRCUIT		1
1-1-9	6005-082	LEAD ASSY, PATTERN PICK-UP		1
2-1-1	1493-3	KNOB, FOCUS		6
2-1-2	1493-2	KNOB, BRIGHT		2
2-1-3	1493-3	KNOB, TRIGGER STABILITY		REF
2-1-4	1493-3	KNOB, EXPAND		REF
2-1-5	3931-001	CONNECTOR, JACK, TRIGGER	J1	1
2-1-6	1922-070	CIRCUIT BREAKER	CB1	1
2-1-7	3200	PILOT LIGHT (95263) (82386 NO. 709-102)	DS2	1
2-1-8	3931-023	CONNECTOR, JACK, PATTERN PICK-UP	J2	1
2-1-9	1493-3	KNOB, PARADE		REF
2-1-10	1493-2	KNOB, POWER		REF
2-1-11	1493-2	KNOB, PATTERN HEIGHT		REF
2-1-12	1493-3	KNOB, POLARITY		REF
2-1-13	1493-3	KNOB, VERTICAL POSITION		REF
2-1-14	7034-503	BEZEL ASSEMBLY		1
2-1-15	7045-032	SCALE, DWELL		1

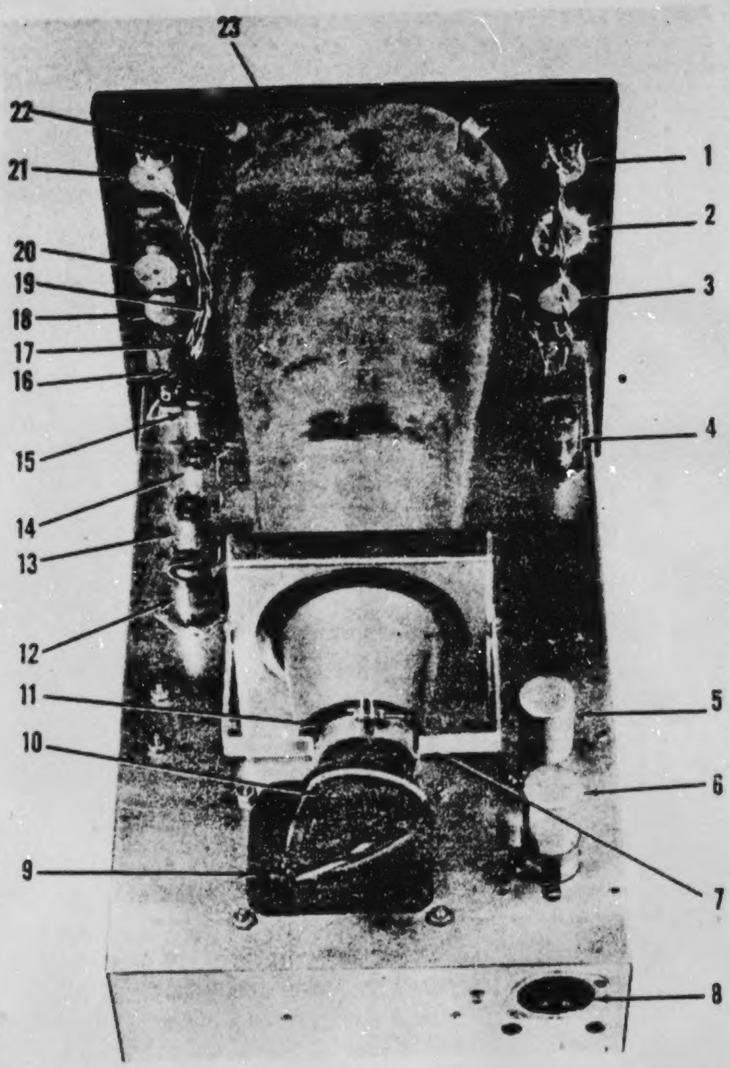
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Figure 6-1. Oscilloscope Internal Components

RECOMMENDED
REPLACEABLE PARTS LIST

Fig. and Index No.	Part Number	Description	Ref. Des.	Quantity Per Unit
6-1-1	NY 1641	RESISTOR, VARIABLE, 0 TO 25K, 1/4 w (71450) (82386 NO. 685-191)	R10	2
6-1-2	212	SWITCH, ROTARY 4 POLE, 2 POSITION (71450) (82386 NO. 762-59)	S2	1
6-1-3	685-098	RESISTOR, VARIABLE, 0 TO 1 MEGOHM (82386)	R8	1
6-1-4, -15	5814A	ELECTRON TUBE (82386 NO. 859-051) ..	V5, V1	2
6-1-5, -6	UPN10137	CAPACITOR 20/20 MFD (09023) (82386 NO. 679-399)	C21, C20	2
6-1-7	7020-818	BRACKET ASSEMBLY (PLUS ATTACHING HARDWARE)		2
6-1-8	6001-056	SOCKET ELECTRICAL CONNECTOR, AC INPUT ...	J3	1
6-1-9	778-320	TRANSFORMER, POWER (82386)	T1	1
6-1-10	763-108	BASE SOCKET (82386)		1
6-1-11	5UP31/ 5DEP31	ELECTRON, TUBE 12 PIN, (95303) (82386 NO. 859-046)	V6	1
6-1-12	5751	ELECTRON, TUBE (82386 NO. 859-054) ..	V4	1
6-1-13	6AU6WB	ELECTRON, TUBE (82386 NO. 859-053) ...	V3	1
6-1-14	5727/ 2D21	ELECTRON, TUBE (82386 NO. 859-052) ..	V2	1
6-1-16	K2A	LAMP, NEON 105-125 VAC (08806) (82386 NO. 709-107)	DS1	1
6-1-17	CM20D681	CAPACITOR, MICA 680 MMFD (81349) (82386 NO. 860-023)	C1	1
6-1-18, -21	NX1151	RESISTOR, VARIABLE, 0 TO 250K, (71450) (82386 NO. 685-051)	R1, R13	2
6-1-19	RC20GF 105K	RESISTOR, 1 MEGOHM, 1/2 W, 10% (81349) (82386 NO. 680-117)	R14	3
6-1-20	M-45	RESISTOR, VARIABLE, 0 TO 200K, (71450) (82386 NO. 685-203)	R11	1
6-1-22	RC20GF473K	RESISTOR, 47K, 1/2 W, 10% (81349) (82386 NO. 680-112)	R35	1
6-1-23	7020-483	TUBE, SHIELD		1

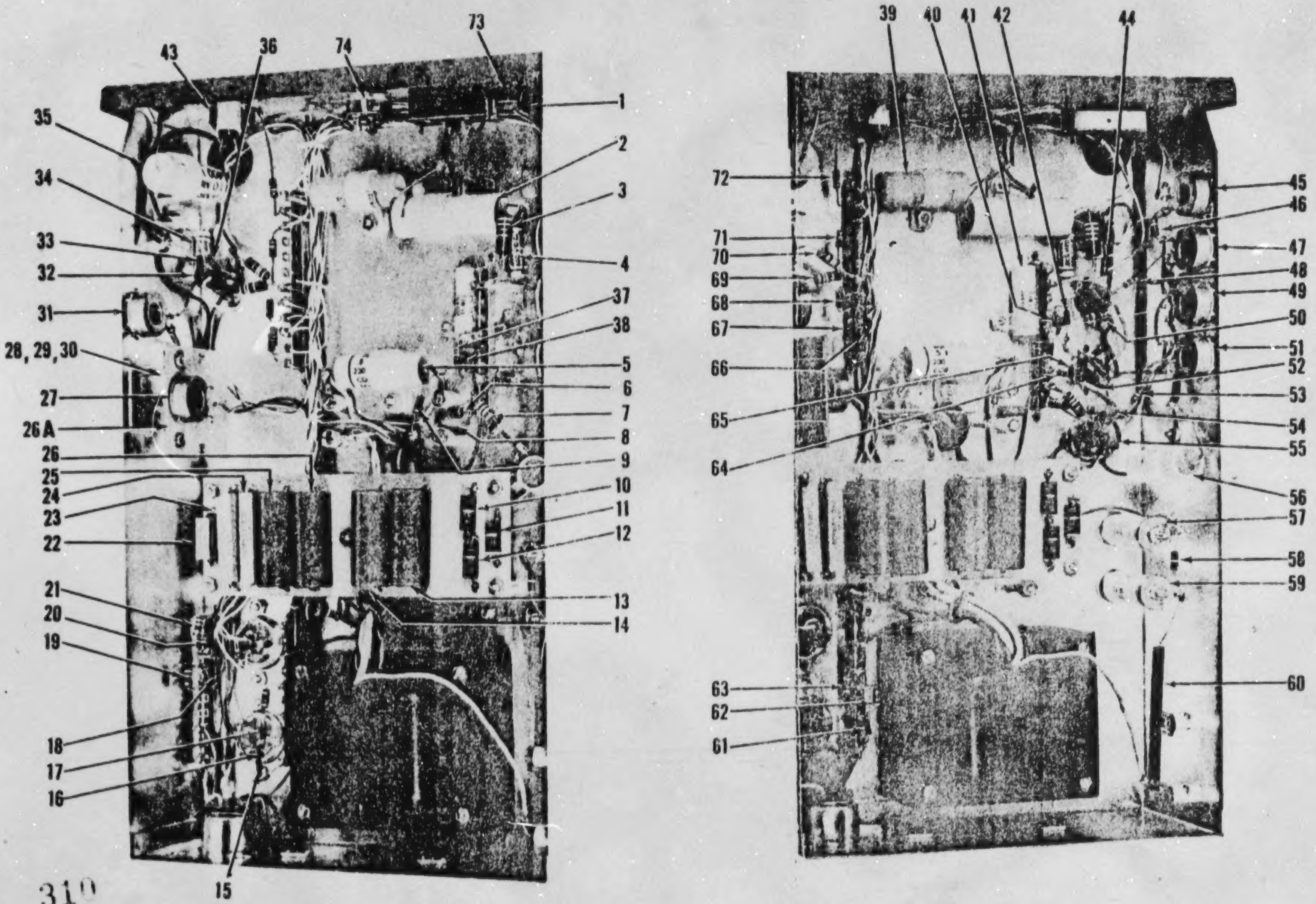
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Figure 6-2. Oscilloscope Internal Components (Bottom View)

RECOMMENDED
REPLACEMENT PARTS LIST

Fig. and Index No.	Part Number	Description	Ref. Des.	Quantity Per Unit
6-2-1	RC20GF103K	RESISTOR,10K, 1/2W, 10% (81349) (82386 NO. 680-205)	R21	1
6-2-2	679-354	CAPACITOR, 0.68 MFD, 200V	C3	1
6-2-3	RC42GF473K	RESISTOR, 47K, 2W, 10% (81349) (82386 NO. 680-174)	R16	1
6-2-4,-34	679-125	CAPACITOR, 0.003 MFD, 400V ...	C2,C12	2
6-2-5,-56	679-129	CAPACITOR, 0.5 MFD,200V	C15,C8	2
6-2-6,-7	RC32GF474K	RESISTOR,470K, 1W, 10% (81349) (82386 NO. 680-146)	R22,R23 R27,R28	4
6-2-8	860-057	CAPACITOR,100 MMFD,6000V	C9	1
6-2-9,-65	RC20GF105K	RESISTOR, 1 MEGOHM, 1/2 W, 10% (81349)(82386 NO. 680-117) ...	R33,R20	REF
6-2-10,-12	RC42GF222K	RESISTOR,2.2K, 2W, 10%,(81349) (82386 NO. 680-165)	R46,R44	2
6-2-11	RC42GF472K	RESISTOR, 4.7K, 2 W, 10%,(81349) (82386 NO. 680-167)	R45	1
6-2-13,-14, -25,-26	BR-1625	CAPACITOR,ELECT.,16 MFD,250V (09023)(82386 NO. 679-155)	C18,C19, C17,C11	4
6-2-15,-16, -17,-18,-61, -20	771-175	DIODE, SILICON	CR7,CR9, CR6,CR5, CR8,CR4	6
6-2-19,-21, -63,-62	RC20GF470K	RESISTOR,47 OHM, 1/2 W, 10% (81349)(82386 NO. 680-095)	R43,R42 R41,R47	4
6-2-22	PW5	RESISTOR, 2.5K, 5W,(75042) (82386 NO. 684-226)	R48	1
6-2-23,-24	684-150	RESISTOR, 6K, 10W	R49,R50	2
6-2-26A	7008-178	RESISTOR BOARD ASSEMBLY		1
6-2-27	MR-7964	RESISTOR,VARIABLE 0 TO 1 MEGOHM,1/4 W, (71450)(82386 NO. 685-205)	R12	1
6-2-28	RC42GF105K	RESISTOR, 1 MEGOHM, 2W, 10% (81349) (82386 NO. 680-181)(LOCATED ON BACK SIDE OF TERMINAL BOARD)	R36	1
6-2-29	RC42GF185K	RESISTOR, 1.8 MEGOHM, 2W, 10% (81349) (82386 NO. 680-144)(LOCATED ON BACK SIDE OF TERMINAL BOARD) ..	R37	1
6-2-30	RC42GF165K	RESISTOR,1.6 MEGOHM, 2W, 5% (81349) (82386 NO. 680-312)(LOCATED BEHIND TERMINAL BOARD)	R38	1

RECOMMENDED
REPLACEMENT PARTS LIST

Fig. and Index No.	Part Number	Description	Ref. Des.	Quantity Per Unit
6-2-31, -51	TPM-450	RESISTOR, VARIABLE 0 TO 100K (71450) (82386 NO. 685-199)	R9, R6	2
6-2-32	RC20GF683K	RESISTOR, 68K, 1/2 W, 10% (81349) (82386 NO. 680-183)	R29	1
6-2-33	RC20GF203J	RESISTOR, 20K, 1/2W, 5% (81349) (82386 NO. 680-151)	R30	1
6-2-35	WMF4W1E	CAPACITOR, 1MFD, 400V (09023) (82386 NO. 679-201)	C10	1
6-2-36	RC20GF563J	RESISTOR, 5.6K, 1/2 W, 5% (81349) (82386 NO. 680-263)	R26	1
6-2-37, -64	RC20GF434J	RESISTOR, 430K, 1/2 W, 5% (81349) (82386 NO. 680-232)	R51, R19	2
6-2-38, -50, -42	IN3193	DIODE, 200V (07688) (82386 NO. 771-117)	CR1, CR2, CR10	3
6-2-39	PM-6P25	CAPACITOR, 0.25 MFD, 600V (09023) (82386 NO. 679-191)	C16	1
6-2-40	U-201	CHOKE, COIL R.F. (99848) (82386 NO. 851-007)	L1	1
6-2-41	679-141	CAPACITOR, 0.15 MFD, 200V	C5	1
6-2-43	685-095	RESISTOR, VARIABLE, 0 TO 500K	R5	1
6-2-44	RC20GF225K	RESISTOR, 2.2 MEGOHM, 1/2 W, 10% (81349) (82386 NO. 680-211)	R15	1
6-2-45	TPM-450	RESISTOR, VARIABLE 0 TO 25K, (71450) (82386 NO. 685-196)	R2	1
6-2-46, -72, -71	RC20GF104K	RESISTOR, 100K, 1/2 W, 10% (81349) (82386 NO. 680-017)	R18, R39, R40	3
6-2-47	TPM-450	RESISTOR, VARIABLE 0 TO 500K, (71450) (82386 NO. 685-195)	R3	1
6-2-48	RC20GF274K	RESISTOR, 270K, 1/2 W, 10% (81349) (82386 NO. 680-063)	R17	1
6-2-49	TPM-450	RESISTOR, VARIABLE 0 TO 1 MEGOHM, (71450) (82386 NO. 685-197)	R4	1
6-2-52	SCM395BP 020A2	CAPACITOR, 3.9 MFD, 3.4V (01295) (82386 NO. 679-345)	C4	1
6-2-53	RC20GF154K	RESISTOR, 150K, 1/2 W, 10% (81349) (82386 NO. 680-024)	R24	1
6-2-54, -55	22R	CAPACITOR, MICA, 180 MMFD, 500V, (09023) (82386 NO. 860-011)	C6, C7	2
6-2-57, -59	MJSB104K30	CAPACITOR, 0.1 MFD, 3000V (99120) (82386 NO. 679-152)	C14, C13	2
6-2-58	RC20GF124J	RESISTOR, 120K, 1/2 W, 5% (81349) (82386 NO. 680-265)	R34	1

RECOMMENDED
REPLACEMENT PARTS LIST

Fig. and Index No.	Part Number	Description	Ref. Des.	Quantity Per Unit
6-2-60	SDC-0151	DIODE, 6KV, (81093) (82386 NO. 774-118)	CR3	1
6-2-66	RC20GF333J	RESISTOR, 33K, 1/2 W, 5% (81349) (82386 NO. 680-282)	R32	1
6-2-67	RC20GF823K	RESISTOR, 82K, 1/2 W, 10% (81349) (82386 NO. 680-125)	R31	1
6-2-68	RC20GF243J	RESISTOR, 24K, 1/2 W, 10% (81349) (82386 NO. 680-209)	R25	1
6-2-73	NY1641	RESISTOR, VARIABLE, 0 TO 25 K , 1/4w (71450) (82386 NO. 685-191)	R7	REF
6-2-74	FA-3000	SWITCH, ROTARY, 120 V (71450)..... (82386 No. 762-168)	S1	1

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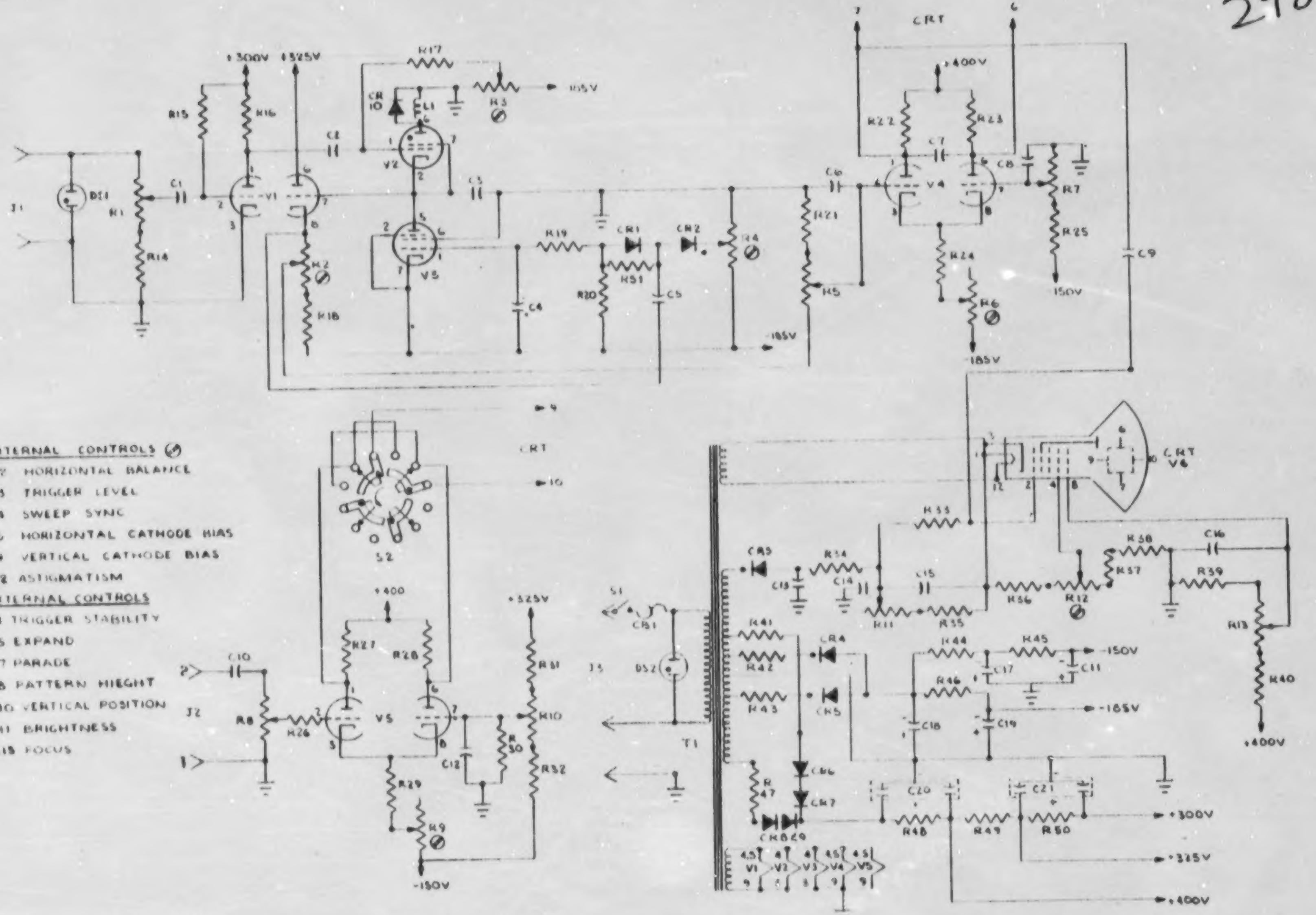

CRT
+300V
+325V
+400V
-150V
-185V
185V
J1
DS1
R1
R14
R15
R16
R17
R18
R2
R3
CR 10
L1
C1
C2
C3
C4
C5
C6
C7
C8
C9
V1
V2
V5
V4
R19
CR1
CR2
R20
R51
R4
R21
R5
R22
R23
R24
R6
R7
R25
S2
J2
C10
R8
R26
R27
R28
R29
R9
C12
R30
R31
R10
R32
S1
CB1
J3
DS2
T1
CR3
C13
R34
C14
C15
R33
R11
R35
R36
R12
R37
R38
C16
R39
R13
R40
CRT V6
R41
R42
R43
CR4
CR5
R44
R45
C17
C11
R46
C18
C19
CR6
CR7
R47
CR8 29
C20
C21
R48
R49
R50

INTERNAL CONTROLS ∅
R2 HORIZONTAL BALANCE
R3 TRIGGER LEVEL
R4 SWEEP SYNC
R6 HORIZONTAL CATHODE BIAS
R9 VERTICAL CATHODE BIAS
R12 ASTIGMATISM

EXTERNAL CONTROLS
R1 TRIGGER STABILITY
R5 EXPAND
R7 PARADE
R8 PATTERN HIEGHT
R10 VERTICAL POSITION
R11 BRIGHTNESS
R13 FOCUS

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ATC-3 AFB, III-71-15089

Model SS-5 Electrical Schematic

72-21789

PREPARE THE MAN

PROGRAMMED TEXT 3ABR47231-1-PT-501
3ABR47231A-PT-501
3ABR47231B-PT-501
3ABR47231C-PT-501
3ABR47330-PT-302B

Technical Training

8-10

Special Vehicle Repairman
(Towing and Servicing Vehicles)
(Crash/Fire Vehicles)
(Refueling Vehicles)
(Materials Handling Vehicles)
General Purpose Vehicle Repairman

MAGNETO CONSTRUCTION, OPERATION, INSPECTION AND MAINTENANCE

8 February 1972

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47231-1-PT-501, 3ABR47231A-PT-501, 3ABR47231B-PT-501, 3ABR47231C-PT-501, 29 November 1971.

OPR: TDWS
DISTRIBUTION: X
TDWS - 900; TTOC - 6

Designed For ATC Course Use

DO NOT USE ON THE JOB

ATC FORM 523 (MAY 71) PREVIOUS EDITIONS OBSOLETE. TRAINING LITERATURE COVER

FOREWORD

This programmed text was developed for use in 3ABR47330, Automotive Repairman's course. It was validated in 1964, using 30 students from the course: 90% of the students used in validation achieved the objectives as stated. The text was adopted in the 3ABR47231, Special Vehicles Repairman course. The text has been in use for the past five years and is considered to be valid for both the subject courses.

OBJECTIVES

After completing this programmed text, you will be able to:

1. State the purpose of a magneto.
2. List the major components of a magneto.
3. From a list, select the statements that describe component operation.
4. Inspect a magneto, using an inspection check sheet.

All objectives will be accomplished with 80% accuracy.

INSTRUCTIONS

This programmed text presents information in small steps, called "frames". After reading the information, you will be required to respond by answering the questions. Simply circle the letter which identifies the correct answer, then check your selection with the correct answer shown at the top of the following page. If you make an error, go over the frame again, to make sure you understand why the answer shown in the text is correct, then proceed to the next frame. If you have trouble understanding the text, ask your instructor for help.

Frame 1.

INTRODUCTION

The magneto supplies high voltage to ignite the fuel-air mixture in a gasoline engine.

A magneto is a complete ignition system in itself; no battery is required, however, hand cranking would be necessary to turn the engine over to cause the magneto to fire.

The advantages of a magneto include dependability, very little maintenance, and minimum weight and space.

QUESTIONS 1 and 2.

? ?

1. What is the purpose of a magneto?

   a. To crank the engine.
   b. To charge the battery.
   c. For ignition only.
   d. To supply all engine electrical requirements.

2. Which of the following is NOT an advantage of the magneto?

   a. Dependability.
   b. Minimum maintenance.
   c. Weight/space factor.
   d. Engine starting.

? ?

Question 1: Response "c" is correct.

Question 2: Response "d" is correct.

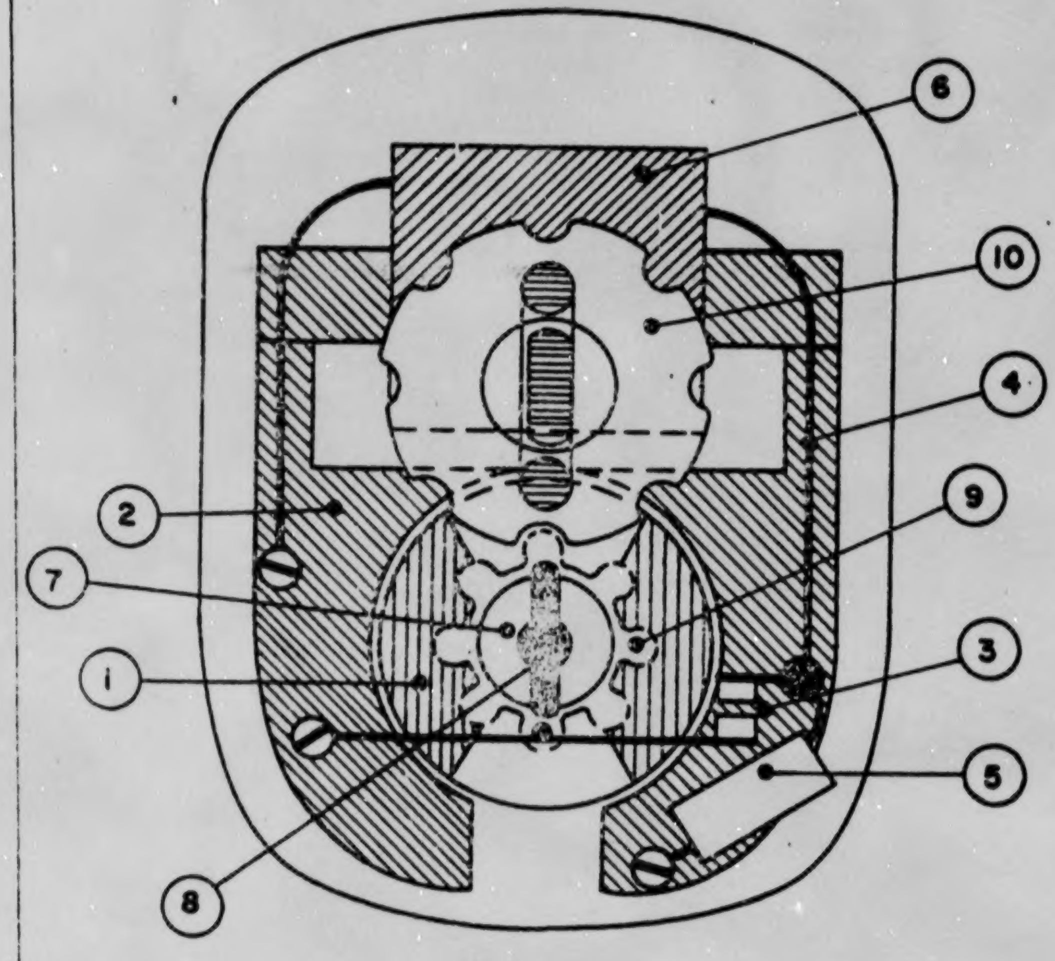

Figure 1.

1. Rotating Magnet
2. Soft Iron Core (Magnetic Circuit)
3. Breaker Points
4. Primary circuit
5. Condenser
6. Coil
7. Shaft
8. Cam
9. Rotor Drive Gear
10. Rotor

The major components of the magneto are listed below; the numbers in parenthesis are references to the numbered item in figure 1.

The rotating magnets (1) are the source of power for the magneto. The magnets are mounted on a ball bearing supported steel shaft (7). At one end of the shaft is the rotor drive gear (9) which meshes with the rotor (10). In front of the rotor gear, on the shaft, is a cam (8) for opening and closing the breaker points (3). Across the points is a condenser (5). The coil (6) has a laminated soft-iron core through its center. This core bridges the iron core (2) built into the magneto housing to complete the magnetic circuit.

QUESTIONS 3 through 6

? ?

3. The source of power for the magneto

   a. is the coil.
   b. is the core.
   c. are the breaker points.
   d. are the magnets.

4. The breaker points are opened and closed by the

   a. rotor gear.
   b. cam.
   c. rotor.
   d. coil.

5. Which of the following magneto components does NOT rotate?

   a. the magnets.
   b. the shaft.
   c. the rotor gear.
   d. the condenser.

6. A magneto is used to

   a. charge the battery.
   b. supply all engine electrical requirements.
   c. crank the engine.
   d. ignite the fuel-air mixture.

? ?

Question 3: Response "d" is correct.
Question 4: Response "b" is correct.
Question 5: Response "d" is correct.
Question 6: Response "d" is correct.

The magneto produces high voltage by magnetic induction. The rotating magnets produce a fluctuating magnetic field in the core. When the points are closed, the magnetic field creates a flow of current in the primary winding (several hundred turns of 0.030-inch diameter wire). The primary winding increases the strength of the magnetic field within the coil. The rotating cam, on the shaft, opens the breaker points. The instant the points are open the built-up magnetic field collapses causing a voltage to be induced in the secondary winding (many thousands of turns of 0.003-inch diameter wire) and the coil fires.

The rotor, timed to the opening of the breaker points, completes the circuits, in turn, to each spark plug. A condenser is installed in parallel with the breaker points to speed up the collapse of the magnetic field and also to reduce arcing across the points.

QUESTIONS 7 through 9

7. The strength of the magnetic field is
    a. increased when the points are closed.
    b. decreased when the points are closed.
    c. increased when the points are open.
    d. constant when points are open or closed.

8. The coil fires when the points are
    a. closed.
    b. wide open.
    c. just open.
    d. about to close.

9. The purpose of the soft iron core is to
    a. produce a fluctuating magnetic field.
    b. create a flow of current in the primary winding.
    c. provide an electric circuit.
    d. provide a magnetic circuit.

Question 7: Response "a" is correct.
Question 8: Response "c" is correct.
Question 9: Response "d" is correct.

At low engine speed (while cranking, either by hand or starter) the output of the magneto is too low to bridge the spark plug gap. To overcome this, an impulse coupler is used. The impulse coupler increases the speed of the rotating shaft to produce a higher voltage. There is a spring in the impulse coupler that must be compressed, and then released to provide the speed-up of the shaft. While the spring is being compressed, the shaft is not rotating and timing is automatically retarded.

QUESTIONS 10 and 11.

? ?

10. To overcome the inability of a magneto to produce high voltage at low speeds

   a. a larger coil is used.
   b. a larger core is used.
   c. a higher capacity condenser is used.
   d. an impulse coupler is used.

11. An impulse coupler is used when cranking an engine to

   a. speed up collapse of the primary magnetic field.
   b. reduce arcing at the points.
   c. retard timing and increase shaft speed.
   d. advance timing and decrease shaft speeds.

? ?

Question 10: Response "d" is correct.
Question 11: Response "d" is correct.

A visual inspection and maintenance of a magneto would include the following:

1. Remove magneto cover (distributor).
2. Inspect bearings for wear, smoothness and lubrication.
3. Inspect distributor for cracks and worn contacts.
4. Inspect rotor for cracks and burned metal strips.
5. Inspect primary wire for loose connections and broken or frayed wires.
6. Check breaker points for pits, alignment and spring tension and the spring for rust spots (Rust spots may cause the spring to break.). Points must be free of oil or dirt.
7. Point gap must be exact; follow manufacturer's specifications (Gage must be clean with no oil film.).

   CAUTION: Due to the very low current flow in the primary circuit, step 7 must be followed to the letter.

8. Inspect seal between body and cover; a broken seal may cause the cover to break during installation.

QUESTION 12.

? ?

12. Why is it necessary to follow manufacturer's specifications when inspecting points and adjusting gap? (Write your answer on the lines below.)

____

____

____

? ?

Question 12: The correct answer is "due to the very low current flow in the primary circuit".

When rotor or rotor drive gears are reinstalled in the magneto, they must be timed to each other. To make this possible, the gears have marks on them to be aligned. Timing is accomplished by setting the mark on the drive gear to the 12 o'clock position (with the magneto right side up). With drive gear set, slide the rotor in mesh with the mark on the rotor aligned with the mark on the drive gear. See Figure 2. The gears are now timed.

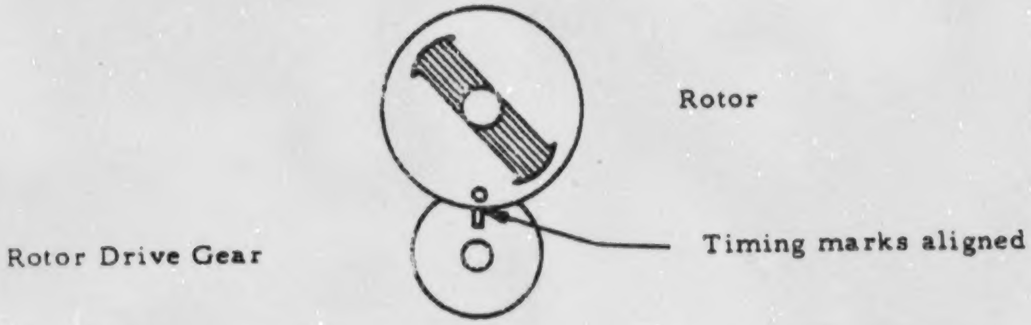

Figure 2 Rotor and Drive Gear

QUESTION 13:

13. Improper timing of the rotor gear and the drive gear would result in

   a. failure of the points to open.
   b. failure of the primary magnetic circuit to collapse.
   c. improper firing of each plug.
   d. failure of the coil to fire.

Question 13: Response "c" is correct. If you failed to answer this question correctly, perhaps you should review Frame 4.

After completion of your inspection and maintenance, the assembled magneto must be tested for output voltage. Secure the magneto in a suitable holder (A vice may be used.). Install one spark plug wire. Hold the wire end 3/8" from the magneto housing. Rotate the impulse coupling, permitting it to snap several times. If the spark jumps the 3/8" gap, the output voltage is adequate.

To stop an engine equipped with a magneto, an insulated circuit is provided to ground the primary circuit of the magneto when the shutoff switch is turned to "OFF".

8-10 304

Vehicle Maintenance Branch
Chanute AFB, Illinois

3ABR47330-WB-305A
15 January 1971

ALTERNATOR AND REGULATOR TESTING USING SIMPSON CBS

OBJECTIVES

After completing this workbook, you will be able to perform a visual inspection and use test equipment to check and/or isolate malfunctions of an AC charging system on a live engine.

EQUIPMENT

	Basis of Issue
Engine Assembly International 6 Cyl	1/2 students
Engine Assembly Valiant 6 Cyl	1/2 students
Simpson Model CBS	1/2 students
Tach-Dwell Tester	1/2 students

PROCEDURE

Using the instructions contained in this workbook, you will test an alternator charging system equipped with a single unit, double contact voltage regulator.

VISUAL INSPECTION

1. Check:
   a. Drive belts -- loose or slipping.
   b. Connections -- dirty, loose or corroded.
   c. Wiring -- too small, too long or frayed.

PRETEST CONNECTIONS

1. Connect the quick disconnect adapter to either post of the battery and leave knife switch open.

2. Connect one ammeter lead to either post of adapter.

3. Connect remaining ammeter lead to other post of adapter.

ALTERNATOR OUTPUT TEST

1. Turn field control knob to open position.

2. Connect one field control lead to ungrounded post of the battery.

OPR: TSDT
DISTRIBUTION: X
TSDT - 500; TSOC - 2

Designed for ATC Course Use Only

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3. Disconnect field wire from alternator field terminal and from the ignition terminal of the voltage regulator.

4. Connect remaining field control lead to alternator field terminal.

5. Place voltage regulator test switch in the direct position.

6. Place test selector switch in 80 amp position.

7. Close knife switch and start engine.

8. Open knife switch.

Note: If any meter should read downscale during tests, merely push the meter reversing switch to the opposite position.

9. Set engine speed at 2500 rpm.

10. Turn field control knob to direct position.

11. Read output on 80 amp scale.

12. What is the alternator's output? ______________

13. Is this within manufacturer's specifications? ______________

14. Turn field control knob to open position and reduce engine speed to idle.

15. Leave all leads connected and proceed with the next test.

INSULATED CIRCUIT RESISTANCE TEST

1. Connect one voltmeter lead to alternator output terminal.

2. Connect remaining voltmeter lead to ungrounded post of battery.

3. Set engine speed at 1500 rpm.

4. Turn field control knob until 10 amps are registered on the 80 amp scale.

5. Close the knife switch.

6. Turn test selector switch to the 4-volt position.

7. Read voltage drop.

8. What is the voltage drop? ______________

9. Is this within manufacturer's specifications? ______________

10. If excessive resistance is indicated, move either voltmeter lead through the circuit to isolate the malfunction.

11. Turn field control knob to open position and reduce engine speed to idle.

12. Open knife switch.

13. Leave all leads connected and proceed with the next test.

GROUND CIRCUIT RESISTANCE TEST

1. Connect one voltmeter lead to ground on the alternator frame.

2. Connect remaining voltmeter lead to grounded post of the battery.

3. Set engine speed at 1500 rpm.

4. Turn field control knob until 10 amps are registered on the 80 amp scale.

5. Close knife switch.

6. Turn test selector switch to the 4-volt position.

7. Read voltage drop.

8. List the voltage drop. ______________

9. Is this within manufacturer's specifications? ______________

10. If excessive resistance is indicated, move either voltmeter lead through the circuit to isolate the malfunction.

11. Turn field control knob to open position and stop engine.

12. Disconnect both field control leads.

13. Reconnect vehicle field wires to field terminal on alternator and to the ignition terminal of the voltage regulator.

14. Leave ammeter leads connected and proceed with the next test.

FIELD CIRCUIT RESISTANCE TEST
(Single Unit Regulator Only)

1. Connect one voltmeter lead to ungrounded post of the battery.

2. Connect remaining voltmeter lead to field terminal on alternator.

3. Turn test selector switch to the 4-volt position.

4. Turn ignition switch to "ON" position.

Note: Do not start engine!

5. Read voltage drop and compare to manufacturer's specifications.

6. What is the voltage drop? ______________

7. Is it within specifications? ______________

8. If excessive resistance is indicated, move either voltmeter lead through the circuit to isolate the malfunction.

9. Turn ignition switch to "OFF."

10. Disconnect voltmeter leads.

11. Open knife switch.

12. Leave ammeter leads connected and proceed with next test.

VOLTAGE REGULATOR TEST

1. Connect one voltmeter lead to alternator output terminal.

2. Connect remaining voltmeter lead to ground on the alternator frame.

3. Disconnect field wire from alternator field terminal.

4. Connect one field control lead to alternator field terminal.

5. Connect remaining field control lead to the wire which was disconnected from the field terminal.

6. Turn test selector switch to the 80 amp position.

7. Close knife switch and start engine.

8. Open knife switch.

9. Set engine speed at 1500 rpm.

10. Turn field control knob until 15 amps are registered on the 80 amp scale.

11. Turn test selector switch to the 16-volt position.

12. Read voltmeter and compare to manufacturer's specification for the series contact setting of the voltage regulator.

13. What is the series contact setting of the regulator? ______________

14. Is it within specifications? ______________

15. Place voltage regulator test switch in the voltage regulator test position.

16. Read voltmeter and compare to manufacturer's specification for the ground contact setting of the voltage regulator.

17. What is the ground contact setting of the regulator? ______________

18. Is this within manufacturer's specifications? ______________

19. Stop engine and remove all test leads.

20. Reconnect field wire to field terminal on alternator.

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PREPARE THE MAN

PROGRAMMED TEXT [illegible]
[illegible]
3ABR47231A-PT-401
[illegible]
[illegible]

Technical Training

8-10

General Purpose Vehicle Repairman
Special Vehicle Repairman
(Towing and Servicing Vehicles)
(Crash/Fire Vehicles)
(Refueling Vehicles)
(Materials Handling Vehicles)

FUNDAMENTALS OF AUTOMOTIVE ELECTRICITY

18 January 1972

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-PT-301B, 4 November 1969.
OPR: TDWS
DISTRIBUTION: X
TDWS - 800; TTOC - 6

Designed For ATC Course Use

DO NOT USE ON THE JOB

FOREWORD

This programmed text was prepared for use in 3ABR47330, Automotive Repairman course. The text was validated in 1964 with 30 students from the course. It has been in use since that time and is considered still valid.

INTRODUCTION

A good automotive repairman should understand the fundamentals of electricity. With this knowledge he can analyze each new unit in an electrical circuit and repair the vehicle with minimum delay. Without this knowledge he would have to learn each new component in the electrical system before he could perform any kind of service on it.

OBJECTIVES

After you have completed this programmed text, you will be able to:

1. Write the Ohm's Law formula from memory, without error.
2. Solve Ohm's Law problems related to voltage, current, and resistance, with 80% accuracy.
3. Given a list of electrical terms and a list of definitions, match the two lists with 80% accuracy.
4. From a list of statements, identify how electricity is produced mechanically.
5. Identify the proper way to connect meters in a circuit.
6. Identify a series circuit without error.
7. Identify a parallel circuit, without error.
8. Identify a series-parallel circuit, without error.

INSTRUCTIONS

This program presents information in small steps called "frames." After each step you are asked to select the correct statements, match some statements, or respond to the information presented in some other way. Use a piece of paper or a card as a mask to cover the printed material. Slide the card or mask down the page until you expose the top of the slashes (////////). One small step is now exposed for your reading. Read the material presented, select your response to the question, and indicate that response on the separate answer sheet provided. DO NOT WRITE IN THIS PROGRAM. Instructions for answering each question are included at appropriate points in the program. After you respond to the question, slide the mask down and compare your answer with the one given in the program. If your answer is correct go on to the next frame; if you are wrong read the frame again.

During your study of this programmed text you will read many electrical terms with which you may not be familiar. An alphabetical list of these terms and their definitions can be found in the next four pages. Feel free to refer to the definition of any term you do not understand.

Begin with the information presented in Frame 1.

ELECTRODE	The positive or negative terminal point of electricity, from which the electricity must travel through air or other substance.
EMF or ELECTROMOTIVE FORCE	That force or pressure which causes current movement in an electrical circuit.
FARAD	When a change of one volt per second across a condenser produces a current of one ampere, the condenser is said to have a capacitance of "one farad."
FIELD or MAGNETIC FIELD	That space which is affected by magnetic lines of force.
FREQUENCY	The number of cycles completed in one second.
GENERATOR	An electromagnetic device used to convert mechanical energy into electrical energy.
GROUND or GROUNDED CIRCUIT	A condition where the electrical circuit is connected or contacted either intentionally or unintentionally to the unit frame or framework.
HYDROMETER	An instrument used for the measurement of the specific gravity of a liquid.
INDUCTION or INDUCTANCE	That force which produces a voltage when a conductor is passed through a magnetic field.
MAGNET	That part which is known to possess magnetism.
MAGNETISM	That property possessed by certain substances (especially iron and steel) by virtue of which they can exert forces of attraction or repulsion, according to fixed laws. (It is the connecting link between electrical energy and mechanical energy.)
MICROFARAD	Since the term "farad" is too large for any practical use, the term "microfarad" (one-millionth of a farad) is used.
MUTUAL INDUCTANCE	That property which causes an induced voltage (EMF) to be set up in a second circuit, as the result of the change of current in the first circuit. (Example: Secondary winding in an ignition coil or transformer.)
OHM	A unit of measurement of resistance.
OHMMETER	An instrument to measure resistance.

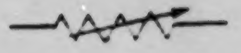
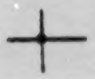
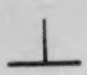
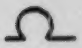
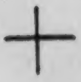
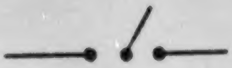
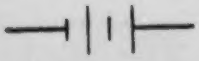
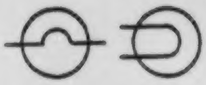
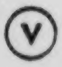
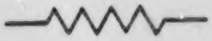
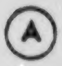
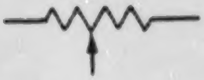
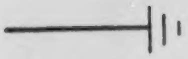
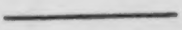
ELECTRICAL TERMS AND THEIR DEFINITIONS

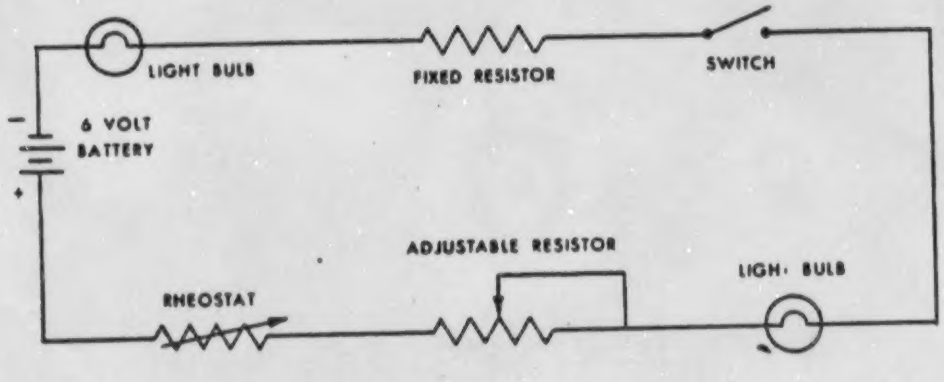
These definitions may differ somewhat from others which you have encountered. They are not intended to be all-inclusive but, rather to serve as reminders so the student can quickly refresh his memory of these electrical terms.

AMMETER	An instrument used for measurement of the rate of flow of electricity.
AMPERE	A unit of measurement of flow of electrical current.
ARC	The travel of electricity through air between two electrodes which produces a flash.
ARMATURE	The moveable part of an electromagnetic device.
BATTERY	A unit (usually composed of lead plates and a sulphuric acid-water electrolyte) which stores electrical energy in a chemical form.
CAPACITY or CAPACITANCE	The property of a system of conductors and dielectrics which permits storage of electrical charges.
COIL	A circular arrangement of electrical conductors so that many conductors are placed side by side, to obtain the resultant effect of their combined magnetic fields.
COMMUTATOR	That portion of an armature consisting of a series of copper segments which come into contact with the brushes.
CONDENSER	An accumulator of electrical energy.
CONDUCTOR	A continuous path (usually metallic) along which electricity can flow.
CORE	A metallic portion (usually laminated) of a coil around which the conductors are wound.
CORONA	Corona is produced when ionization of gases (air) is concentrated either around a conductor or between electrodes. This is often the condition around high voltage transmission lines. A resultant flow is often visible in darkness.
CURRENT	The quantity of flow of electricity.
CYCLE	A complete set of recurring values.
DIELECTRIC	An insulating medium which intervenes between two conductors to prevent the flow of current from one conductor to another. Usually air, rubber, mica, glass, fiber, wood, or ebonite.

OHM'S LAW	A law of electricity regarding the relationship between voltage, current, and resistance. It requires a pressure of one volt to force one ampere of current through one ohm of resistance. The formula is: volts = amperes x ohms, or $E = I \times R$.
OPEN CIRCUIT	Any break or lack of contact i$\overset{n}{s}$ an electrical circuit, either intentional or unintentional.
OSCILLATION	A rapid back and forth (reciprocating) movement.
OZONE	A faint blue gas with a characteristic smell, produced when an electrical discharge is passed through air, creating a concentration of oxygen (or changing oxygen into ozone) O_3.
PARALLEL CIRCUIT	A circuit offering two or more paths for current to flow.
PERMANENT MAGNET	A part which retains the magnetic force, even though the force which produced the magnetism is discontinued.
RESISTANCE	The property of an electrical circuit which tends to prevent or reduce the flow of current.
SERIES CIRCUIT	A single continuous circuit, in which the flow of current would stop if broken at any one point.
SHORT CIRCUIT	Generally an unintentional contact between two conductors, caused by faulty insulation or lack of insulation. This condition allows the current to bypass its normal circuit.
STARTING MOTOR	An electromagnetic device, which can convert electrical energy into mechanical energy used for cranking the engine.
VOLT	A unit of measurement of electrical pressure.
VOLTAGE	That property of an electrical circuit that causes current to flow.
VOLTMETER	An instrument used to measure electrical pressure.
WATT	A unit of measurement of electrical power. 1 watt = 1 volt x 1 ampere. 1 kilowatt = 1,000 watts.

ELECTRICAL DEVICES AND THEIR SYMBOLS

VOLTAGE	E OR V	RHEOSTAT	
CURRENT	I OR a	CONNECTION	 OR 
RESISTANCE	R OR 	CROSSING	
POSITIVE TERMINAL	+	SINGLE POLE DOUBLE THROW SWITCH	
NEGATIVE TERMINAL	–	BATTERY	
LIGHT BULB		VOLTMETER	
FIXED RESISTOR		AMMETER	
ADJUSTABLE RESISTOR		GROUND	
		CONDUCTOR	


LIGHT BULB
FIXED RESISTOR
SWITCH
–
6 VOLT BATTERY
+
RHEOSTAT
ADJUSTABLE RESISTOR
LIGH· BULB

Frame 1.

Anything that occupies space and has weight is "matter." This book, the print on it, a tree, and air are all examples of matter. All matter consists of smaller units called "molecules." Air, for example, is formed of molecules. Molecules consist of atoms. Atoms are made up of protons, electrons, and neutrons. These divisions of atoms have positive, negative, or neutral electrical charges.

The proton is a basic particle having a single positive (+) charge.

The electron is a particle having a single negative (-) charge.

The neutron is a basic particle having no charge.

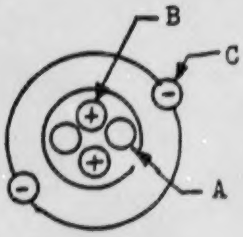
QUESTIONS 1 through 3

Match the letters used to identify the parts of an atom in the accompanying diagram to the correct term.

1. Proton.

2. Electron.

3. Neutron.



//////////////////

1. B 2. C 3. A

QUESTIONS 4 through 6

Match the terms and definitions below by recording the letter used to identify each definition on the separate answer sheet provided.

4. Neutron. A. A negatively charged particle in an atom.

5. Electron. B. A positively charged particle in an atom.

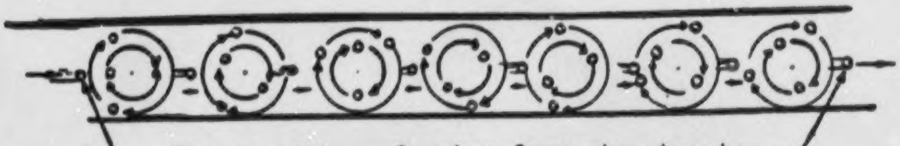
6. Proton. C. A particle of an atom having no charge.

//////////////////

4. C 5. A 6. B

Frame 2.

When in an uncharged state, each atom is neutralized with equal positive and negative charges. The continuous electron movement is then concentrated about each individual nucleus. With some disturbing force (an excess of electrons in any part of the circuit) there is a drift of electrons from one atom to another. The drift is referred to as a "flow of current." The atoms shown in the illustration below are greatly enlarged in order to show this movement of electrons. Electrons drift at approximately 186,000 miles per second.



Electrons transferring from atom to atom

Current flow is measured in amperes. One ampere is about the amount of current flow a 100-watt light bulb will draw; however, it takes more than six billion billion electrons passing any given point in one second to equal one ampere.

QUESTION 7.

Indicate on your answer sheet those statements below that are true.

a. Electrons will drift from one atom to another when there are an equal number of protons and electrons in the atom.

b. An excess of positive charges will attract electrons.

c. When an atom is balanced it has two electrons to each proton.

d. An unbalanced situation will cause electrons to move from atom to atom.

e. The unit of measurement for current flow is the ampere.

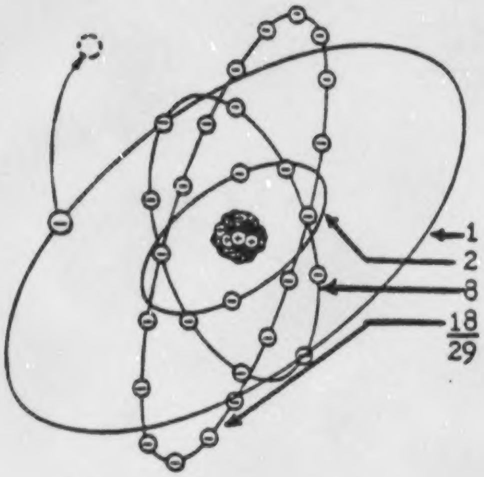
//////////////////

"b," "d," and "e" are true statements.

There are two different theories about the direction of current flow. These theories are the "electron theory" and the "Franklin theory."

The electron theory is that electrons and current both move from negative (-) to positive (+).

The Franklin theory is that electrons move from negative to positive but current flows from positive to negative. Most of the commercial manuals you will be using follow this theory.



In order for electrons to drift, they must have a path or circuit to move in. Materials having an abundance of free electrons are referred to as conductors. Copper wire is used in circuits of automotive vehicles because it has m any free electrons in it. An atom of copper has 29 electrons circling around its nucleus in four different orbits (see illustration to the left). Note that the outer orbit has only one electron. This electron can move away from its nucleus rather easily and become a free electron. A copper wire is made up of countless atoms and therefore has a tremendous number of these free electrons. Some other good conductors are aluminum, zinc, and silver.

An insulator, or nonconductor, is a substance that has a frw free electrons. Since current flow depends upon the movement of free electrons along a circuit, the lack of free electrons in an insulator will prevent the flow of current. The insulation on electrical wiring and electrical devices prevents the free electrons from taking a short circuit, and covers and protects the conductor. Insulators include rubber, porcelain, glass, bakelite, and certain kinds of fiberboard.

Frame 4.

QUESTION 8.

Materials having a large number of free electrons make good

a. atoms.

b. conductors.

c. molecules.

d. insulators.

///////////////////

"b" is correct

QUESTION 9.

Materials having very few electrons make good

a. atoms.

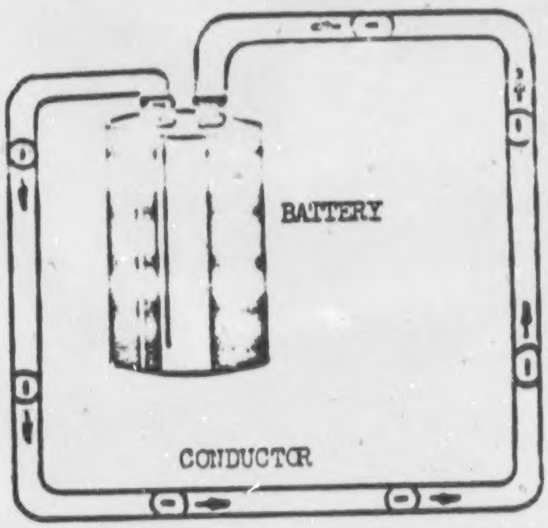
b. conductors.

c. molecules.

d. insulators.

///////////////////

"d" is correct



As mentioned earlier, there must be some disturbing force to create a drift of electrons. In order to create a drift of electrons (current flow) through a circuit, it is necessary to have electrical pressure (voltage or electromotive force). A storage battery is used as one source of electrical pressure for automotive vehicles. Note in the figure to the right that the electrons flow away from one post of the battery and toward the other post. The reason for this is that a battery creates an excess of electrons at one post and it has a deficiency of electrons at the other post. The pressure or force in an electrical circuit that causes current to flow is called voltage. When current flows, the battery voltage will decrease.

QUESTION 10.

The drift of free electrons from one atom to another is called

a. current flow.

b. charging.

c. voltage.

d. electron balance.

///////////////////

a. is correct

Frame 6.

QUESTION 11.

The drift of free electrons is caused by

a. balanced atoms.

b. conductors.

c. electrical pressure.

d. insulation.

//////////////////

c. is correct

QUESTION 12.

That property of an electrical circuit that causes current flow is

a. electrons.

b. protons.

c. neutrons.

d. voltage.

//////////////////

d. is correct

Frame 7.

A copper wire will conduct electricity with relative ease, but it still offers some resistance to current flow. The amount of resistance in wires will vary with the diameter, length, temperature, and the type of material. A long wire offers more resistance than a short wire of the same material. A large diameter wire offers less resistance than a small diameter wire. Iron wire has fewer free electrons than copper wire. Therefore, iron wire offers more resistance than a copper wire of the same temperature, length, and diameter. The resistance of most metals increases with an increase in temperature.

The unit of measurement for resistance is the ohm. One ohm is the amount of resistance that will limit the current flow to one ampere when one volt of electrical pressure is applied.

When more than one path is provided for current flow, the flow will divide according to the resistance, with the greatest current flow taking the path of the least resistance.

QUESTION 13.

On your answer sheet indicate which of the following statements are true.

a. Resistance is measured in ohms.

b. A large diameter wire offers more resistance than a small diameter wire.

c. That property of an electrical circuit that tends to prevent or reduce current flow is called "resistance."

d. Copper wire has a large number of free electrons; therefore, a small amount of resistance.

e. An increase in temperature will increase the resistance of a wire.

///////////////////

a, c, d and e are true statements

Frame 8.

QUESTIONS 14 through 17

On your answer sheet indicate the letter that identifies each term on the right for each definition in the left hand column.

14. A unit of measurement of resistance.

15. That property of an electrical circuit that causes current to flow.

16. That property of an electrical circuit that tends to prevent or reduce current flow.

17. A unit of measurement of current flow.

a. Resistance.
b. Volt.
c. Ampere.
d. Voltage.
e. Ohm.

//////////////////

14. e 15. d 16. a 17. c

QUESTIONS 18 through 21.

On your answer sheet indicate the letter that identifies each term on the right for each definition in the left hand column.

18. A unit of measurement of electrical pressure (electromotive force).

19. A particle of an atom that contains no electrical charge.

20. A positively charged particle of an atom.

21. A negatively charged particle of an atom.

a. Volt.
b. Ohm.
c. Electron.
d. Proton.
e. Neutron.

//////////////////

18. a 19. e 20. d 21. c

Note: If you found that you could not accurately match these terms and their definitions without looking back to the answers, go back and study the term(s) that gave you trouble before continuing any further with the program.

In order to have current flow the electrons must have a path or circuit to move through. An electrical circuit is a closed path for the flow of electrons. The starting point is some type of device to create electrical pressure such as a battery or generator. The circuit is not complete until the conducting path can be traced back to the starting point where the voltage originates. The frame of an automotive vehicle completes the circuit back to its source. This is known as a "ground circuit."

Circuits may be classified as "series," "parallel," and "series-parallel." A series circuit has only one complete path for current flow. A parallel circuit has two or more paths for current flow. A series-parallel circuit is a combination of the two in that part of the circuit that has two or more paths for current flow but these parallel circuits are in series with another section of the circuit that has only one path for current flow.

QUESTIONS 22 through 24.

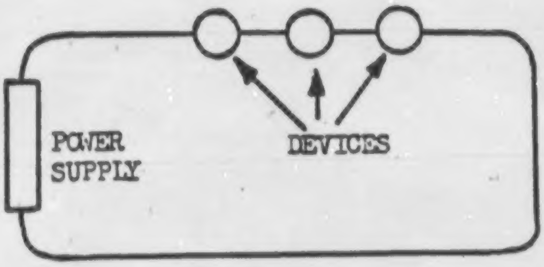
On your answer sheet indicate the kind of circuit represented by each of the following diagrams.

a. Series-parallel

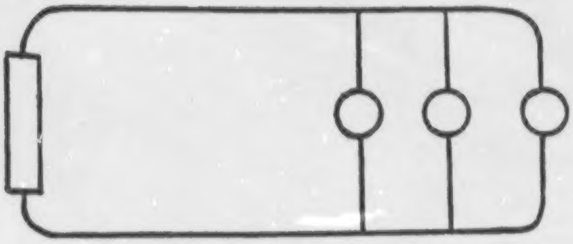
b. Parallel

c. Series

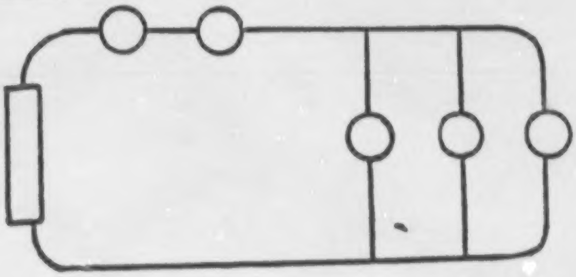
22.



23.



24.



Frame 10.

QUESTION 25.

On your separate answer sheet, black out the letter(s) corresponding to each true statement given below.

a. A parallel circuit has two or more paths for current flow.

b. A series circuit has only one path for current flow.

c. In a parallel circuit, if one device develops an open circuit all current flow will cease.

d. If one device in a series circuit develops an open circuit all current flow will cease.

e. A circuit is not complete until it can be traced back to the source of power.

//////////////////

a, b, d, and e are true statements

REVIEW

In a series circuit, the voltage will divide (be dropped) across each resistor, in accordance with the ohmic resistance of each resistor. Around the circuit, all the voltage will be used up. In other words, the sum of all the voltage drops around a series circuit must equal the source voltage.

The current flow will be the same in any and all parts of a series circuit.

In a parallel circuit, the voltage applied to all parallel branches is the same.

The current will divide across the parallel branches according to the resistance present in each path, with the greatest current in the circuit having the least resistance.

The relationship between current, voltage, and resistance in an electrical circuit conform to a rule known as "Ohm's Law." This law states: "Voltage is equal to current flow times resistance," which simply stated means that one volt will push one ampere of current through one ohm of resistance.

QUESTION 26

Indicate which letter identifies the correct answer below:

Ohm's Law is the principle which states that a

a. current flow of one ampere will cause one ohm of resistance in a circuit having one volt of electrical pressure.

b. pressure of one volt will push one ampere of current flow through one ohm of resistance.

c. resistance of one ohm will produce an electrical pressure of one volt in a circuit having one ampere of current flow.

d. circuit having an equal amount of current flow, voltage, and resistance is a complete circuit.

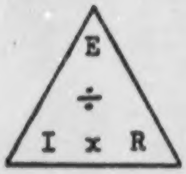
///////////////////

b. is correct

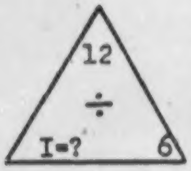
Frame 12.

Ohm's Law must be understood before it is possible to trace troubles in automotive electrical circuits. A majority of electrical troubles in automotive vehicles result from increased resistance in circuits. This can be caused by bad connections, faulty wiring, dirty or burned contacts in switches, and similar troubles. If voltage remains constant and resistance increases, current flow will be decreased. However, not all troubles are caused by increased resistance. If resistance remains constant and voltage increases, current flow will increase. This condition could cause serious damage to units in the electrical system.

Ohm's Law can be stated as a mathematical formula as: E = I x R, where E = voltage, I = current, and R = resistance. The Ohm's Law triangle may help you to remember the formula. This formula can be used to solve any problem in electrical circuits when any two of the factors are known.



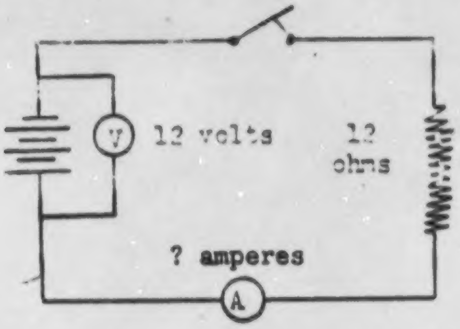
The formula for finding the unknown quantity will be given by covering the unknown factor of the triangle and performing the simple mathematical problem left showing. For example: Given 12 volts of electrical pressure and 6 ohms of resistance; cover the "I" in the triangle and you have E ÷ R left. 12 divided by 6 = 2 amperes of current flow.



Now, use the formula to solve the following problems.

QUESTION 27.

In the circuit shown to the right, the current flow is _____ amperes.



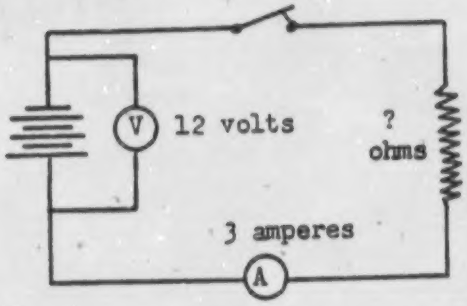
V
12 volts
12 ohms
? amperes
A

///////////////////

1 ampere

QUESTION 28.

In the circuit shown to the right, the resistance is _____ ohms.



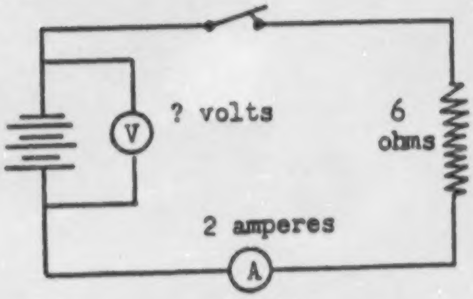
V
12 volts
? ohms
3 amperes
A

///////////////////

4 ohms

QUESTION 29.

In the circuit shown to the right, the applied voltage is _____ volts.



V
? volts
6 ohms
2 amperes
A

///////////////////

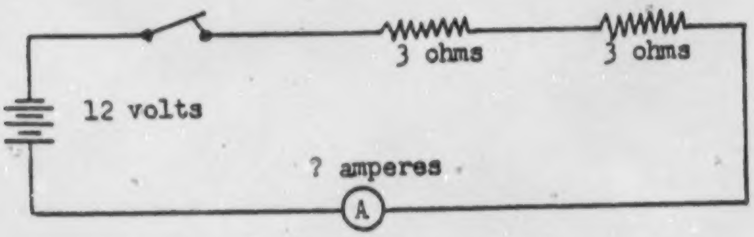
12 volts

Frame 14.

When you have two or more resistors in series, add the resistor values together to find the total resistance. Then, solve the problem the same as you would for one resistor.

QUESTION 30.

In the circuit shown below, the current flow is ________ amperes.



///////////////////

2 amperes

QUESTIONS 31 through 33.

31. A circuit with 12 volts applied and 4 ohms of resistance will have __________ amperes of current flow.

32. A circuit with 3 amperes of current flow and 4 ohms resistance will have __________ volts applied.

33. A circuit with 6 amperes of current flow and 12 volts applied voltage will have __________ ohms of resistance.

///////////////////

31. 3 32. 12 33. 2

Frame 15.

No study of electrical fundamentals is complete without mentioning the subject of magnetism. Although magnetism cannot be fully explained, there are some rules that have been established through research which apply to the behavior of the lines of force as shown in the illustrations shown on the lower part of this page.

a. Lines of force outside the magnet pass from the north to the south pole.

b. Lines of force act as rubber bands and try to shorten to a minimum length.

c. Lines of force repel each other along their entire length.

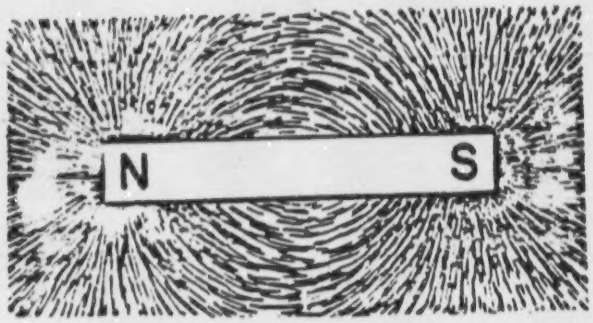
d. Lines of force never cross each other.

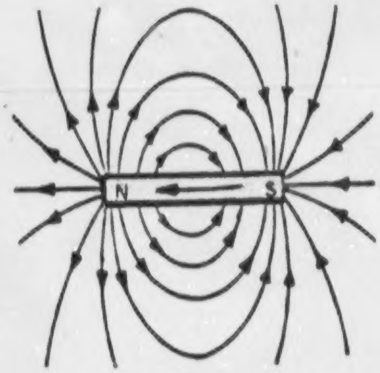
e. Lines of force cannot be insulated but grow weaker with distance.

f. Lines of force are referred to as "the magnetic field" of the magnet.

g. The closer the poles the stronger the magnetic field.

h. Like poles repel each other - unlike poles attract each other.





Frame 16.

QUESTION 34.

As shown in the figures in Frame 15, the magnetic lines of force travel from

a. north to south inside and south to north outside the magnet.

b. south to north inside and outside the magnet.

c. south to north inside and north to south outside the magnet.

d. north to south inside and outside the magnet.

///////////////////

c. is correct

QUESTION 35.

The magnetic field of a magnet can be defined as

a. the length times the width of the magnet.

b. that space which is affected by magnetic lines of force.

c. the length times the width times the thickness of the magnet.

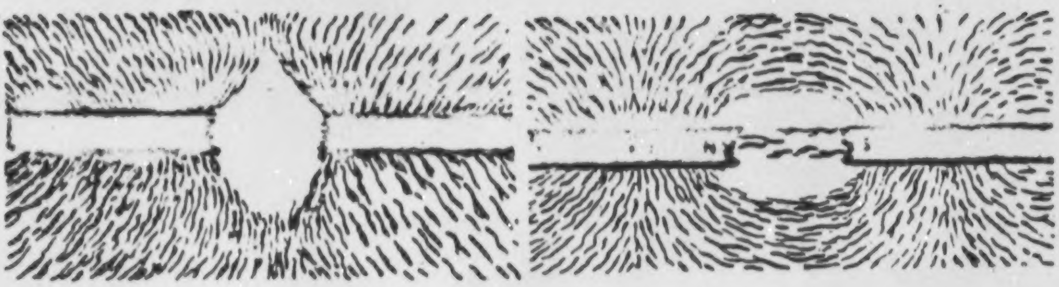
d. that area around the place where natural magnets are found.

///////////////////

b. is correct

Frame 17.

QUESTIONS 36 through 38.



Like Poles

Unlike Poles

36. As shown in the figures above, in reference to magnets

a. like poles repel.

b. the north pole of one magnet will attract the north pole of another magnet.

c. unlike poles repel.

d. the south pole of one magnet will attract the north pole of another magnet.

37. Which of the following is a correct statement about magnets?

a. The north pole of one magnet will attract the south pole of another magnet.

b. Unlike poles repel.

c. The north pole of one magnet will attract the north pole of another magnet.

d. Like poles attract.

38. "That space which is affected by magnetic lines of force" is the definition of a/an

a. magnetic field.

b. arc.

c. magnet.

d. north pole.

//////////////////

36. a & d 37. a. 38. a.

Frame 18.

Magnetism affects cobalt, nickel, iron, and their alloys.

Residual magnetism is the amount of magnetic effect remaining in the core of an electromagnet when the electricity is turned off.

Soft iron is easy to magnetize but it also loses its magnetism easily.

Hard iron or steel is difficult to magnetize but will retain its magnetism for long periods of time.

Magnets can be demagnetized by applying heat, vibration, or alternating current to them.

Some magnets have the capability of retaining their magnetism for indefinite periods of time and are known as "permanent magnets." Permanent magnets are made of hard metal. Magnets can be made of soft metal which does not retain magnetism and are therefore called "temporary magnets." A temporary magnet, when wrapped with coils of insulated wire, becomes an electromagnet.

QUESTIONS 39 through 41.

On your separate answer sheet indicate the letter that identifies the description from the right column for each type of magnet listed in the left column.

39. Temporary magnet.

40. Permanent magnet.

41. Electromagnet.

A. A soft iron core wrapped with insulated wire.

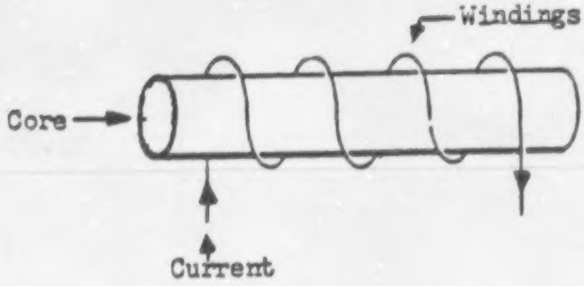
B. A magnetized steel bar.

C. A magnetized soft iron bar.

//////////////////////////////

39. C   40. B   41. A

The strength of permanent and temporary magnets is constant, but the strength of an electromagnet can be increased or decreased by changing any one of the three parts of the electromagnet. Note the three parts of an electromagnet shown in the diagram below. The number of turns (coils of wire) multiplied by the number of amperes of current flow equals the strength of an electromagnet in "ampere-turns."



QUESTION 42.

On your answer sheet black out the letters to indicate the true statements below.

a. An increase in current flow will increase the strength of an electromagnet.

b. An increase in the number of windings will decrease the strength of an electromagnet.

c. A decrease in the number of windings will decrease the strength of an electromagnet.

d. Removing the iron core will decrease the strength of an electromagnet.

e. Decreasing current flow will increase the strength of an electromagnet.

f. The strength of an electromagnet can be increased by removing the iron core.

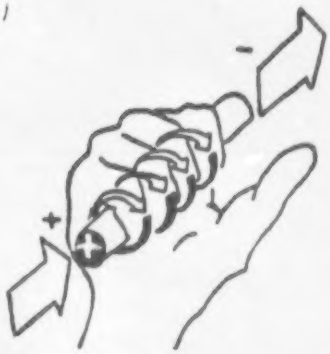
g. An electromagnet with 2 amperes of current flow and 200 turns of wire is a 400 ampere-turn electromagnet.

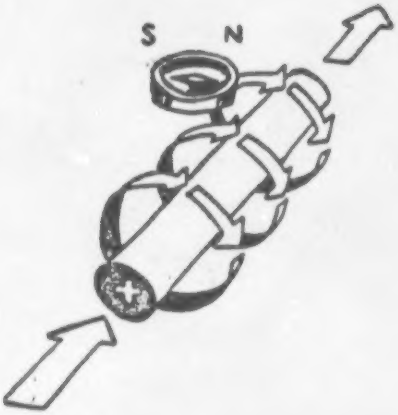
//////////////////////////////

a., c,. d., and g. are correct

Frame 20.

When current flows through a conductor, a magnetic field is produced around that conductor. When the direction of current flow is known, the direction of the lines of force around the conductor can be found by use of the "right hand rule" as shown in the left part of the illustration below. To use this right hand rule to find the direction of the lines of force, point your thumb in the direction of the current flow and your fingers will point out the direction of the lines of force. If neither the direction of current flow nor the direction of the lines of force are known, use a compass to find the direction of the lines of force as shown in the right hand portion of the illustration below and then use the right hand rule to find the direction of current flow by pointing your fingers in the direction of the lines of force and your thumb will point out the direction of current flow. The right hand rule is applicable under the theory that current flows from positive (+) to negative (-).

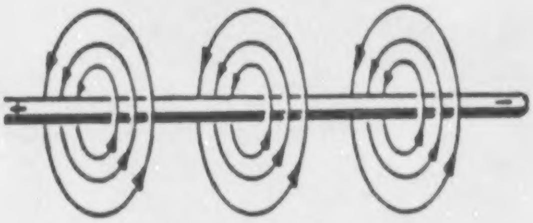




QUESTION 43.

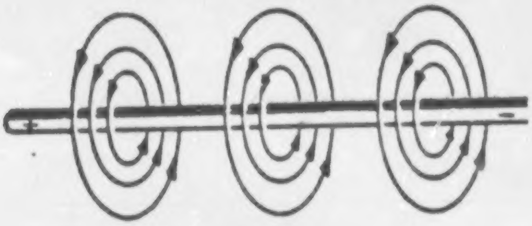
On your separate answer sheet, black out the letter that identifies the illustration below that accurately shows the direction of current flow and the lines of force.

a.



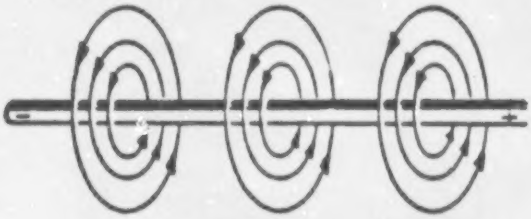
Current flow ----→

b.



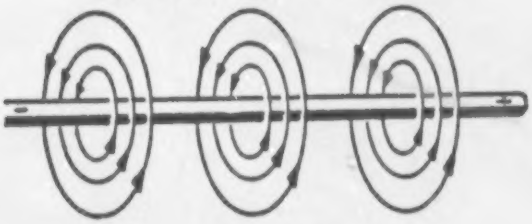
Current flow ----→

c.



Current flow ----→

d.



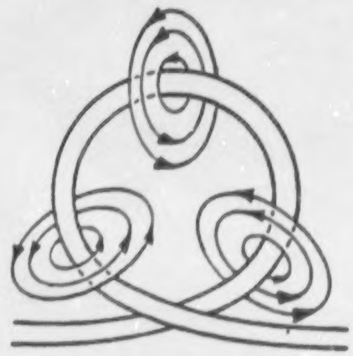
Current flow ---→

//

b. is correct

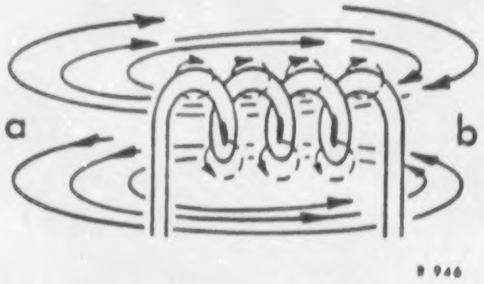
Frame 22.

If a current-carrying conductor is formed into a loop, all of the lines of force around the conductor must pass through the inside of the loop which intensifies the density of the lines of force in the center. Observe an example of this in the illustration below. This greater density creates a much stronger magnetic effect with the same amount of current. A series of loops will create the same effect as a permanent magnet with a north and a south pole. All lines of force inside the coil point in the same direction. In a bar magnet the lines of force inside the magnet travel from the south pole to the north pole. The direction of the lines of force inside a coil is the same as in a bar magnet.



QUESTION 44.

Label the north and south poles of the electromagnet shown in the illustration below.



//////////////////////////////

a. North

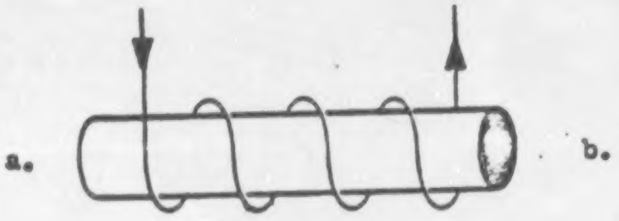
b. South

Another method of determining the poles of an electromagnet is to wrap your right hand around the coil with your fingers pointing in the direction of the current flow; your thumb will point toward the north pole.

QUESTION 45.

On your separate answer sheet, indicate the polarity of the poles in the illustration below.

Note: The arrows show the direction of the current flow.



ANSWER WILL BE FOUND TOWARD THE BOTTOM OF PAGE

The previous illustrations of electromagnets show coils similar to a spring. Electromagnets can be formed into many shapes. The field coils of generators and starters, the primary winding in an ignition coil, the coils in electric gauges, the coils in relays, and even the windings in a starter armature can be considered as electromagnets. They all produce magnetism by electrical energy.

Answer to QUESTION 45: a. South b. North

Frame 24.

QUESTION 46.

Indicate which of the following units make use of electromagnets by blacking out the respective letters.

a. Generator

b. Toggle switch

c. Rheostat

d. Electric gauges

e. Battery

f. Starter

g. Relay

h. Bar magnet

i. Circuit breaker

j. Fuse

k. Resistor

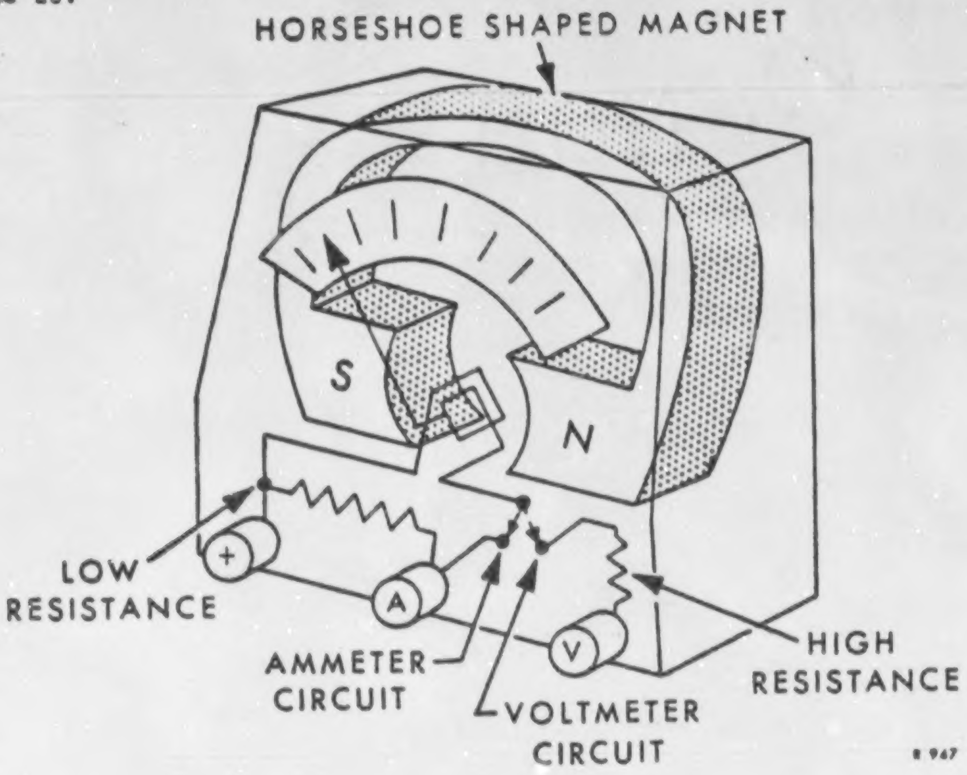
l. Ignition coil

///////////////////

a., d., f., g., and l. make use of electromagnets

Diagnosing troubles in electrical circuits is one of the most important jobs of an automotive mechanic. Each unit in an electrical system is built to a specification which means that it should have a certain amount of resistance, current flow, and voltage applied. In order to determine if the component is satisfactory it is necessary to measure these properties. This requires the use of electrical meters. An ammeter is used to measure the flow of current and is read in amperes. A voltmeter is used to measure the electrical pressure (voltage, or electromotive force) and is read in volts. An ohmmeter is used to measure the resistance and is read in ohms. When a voltmeter is used to measure across a device in a circuit, the reading obtained is called "voltage drop." This reading divided by the current flow can be used to determine the amount of resistance in a "live" circuit.

341


HORSESHOE SHAPED MAGNET
S
N
+
A
V
LOW RESISTANCE
AMMETER CIRCUIT
VOLTMETER CIRCUIT
HIGH RESISTANCE
# 947

The illustration above shows a typical meter movement. Note that the voltmeter circuit has a high resistance in series with the meter movement coil.

The ammeter has a low resistance in parallel with the meter movement coil. An ammeter is never connected in a circuit that has no resistance because the low internal resistance in the ammeter will allow maximum current and burn out.

The high internal resistance in the voltmeter prevents excessive current flow and allows it to be used to check a power supply.

The voltmeter is connected in parallel to the circuit being checked so that it allows the current flow of the circuit to continue undisturbed.

The ammeter is connected in series with the circuit but the low internal resistance allows the current to continue in the circuit undisturbed.

Frame 27.

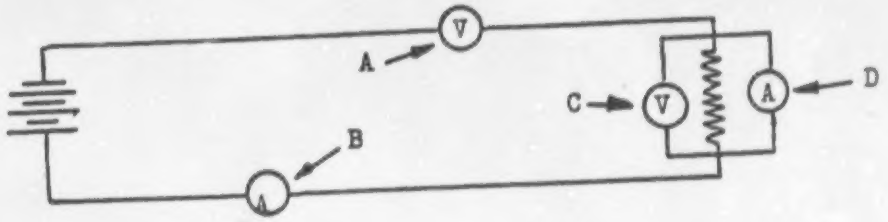
Electrical meters must be correctly connected to the circuit to accurately measure the voltage, current, and/or resistance.

A voltmeter is connected in parallel with the circuit or device being checked and is used to measure voltage (emf, electrical pressure, or electromotive force).

An ammeter is connected in series with the load or control resistance and is used to measure current flow. The positive terminal (+) (red) of meters is connected into the circuit in the direction the current is coming from.

QUESTIONS 50 through 53.

50. On your separate response sheet black out the letter that identifies the instrument being used to correctly measure voltage in the diagram shown below.



51. On your separate response sheet black out the letter that identifies the instrument being used correctly to measure current in the diagram shown above.

52. A voltmeter must be connected in

a. parallel when being used to measure current.

b. series when being used to measure voltage.

c. parallel when being used to measure voltage.

d. series when being used to measure current.

53. An ammeter must be connected in

a. parallel with the switch or fuse for the circuit.

b. series when being used to measure voltage.

c. parallel with one device in the circuit.

d. series when being used to measure current.

///////////////////

50. C 51. B 52. c 53. d

Frame 28.

QUESTIONS 54 through 59.

On your response sheet record the letter that identifies each term on the right with its definition as given in the left column.

54. An instrument used to measure electrical pressure.

55. A circuit having only one complete path for current flow.

56. An instrument used to measure resistance.

57. The principle which states that a pressure of one volt will force one ampere of current flow through one ohm of resistance.

58. A circuit having two or more paths for current flow.

59. An instrument used to measure current flow.

A. Ohm's Law.

B. Series circuit.

C. Ammeter.

D. Voltmeter.

E. Parallel circuit.

F. Ohmmeter.

//////////////////////////////

54. D 55. B 56. F 57. A

58. E 59. C

Note: If you found that you could not accurately match the terms and definitions above without looking at the answers, go back and study the terms that gave you trouble before continuing any farther with the remainder of this program.

Meters are used in maintaining, repairing, and troubleshooting electrical circuits and devices. Some troubles that can be detected by using meters are open circuits, short circuits, and unwanted grounds. An open circuit is a break or a lack of contact in an electrical circuit or device. A short circuit is where a bare wire is touching another bare wire, giving the current a different path to travel than that intended. An unwanted ground is where a bare wire is touching the frame or another metal surface that is grounded. This is not to be confused with a ground which was designed to complete the circuit through the vehicle frame. Poor connections or very small wire (cable) can cause excessive resistance.

QUESTIONS 60 through 63.

After the corresponding number on your response sheet black out the letter that identifies each definition on the right with the term it defines as given in the left column.

60. Unwanted ground.
61. Excessive resistance.
62. Short circuit.
63. Open circuit.

A. A break or lack of contact in an electrical circuit.

B. Where a bare wire is touching another bare wire giving the current a different path to travel than was intended.

C. Dirty or loose connections, cable too small, or frayed.

D. Where a bare wire is touching the frame or another metal surface that is grounded.

//////////////////////////////

60. D 61. C 62. B 63. A

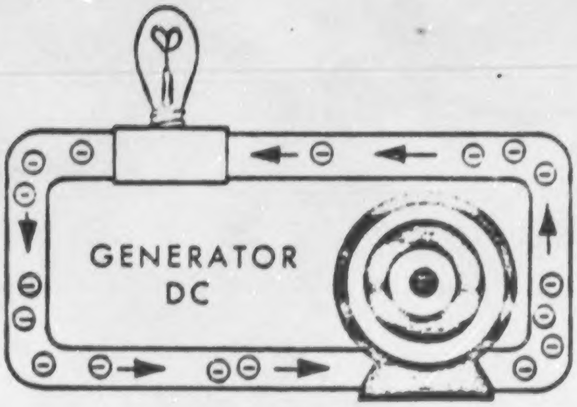
Frame 30.

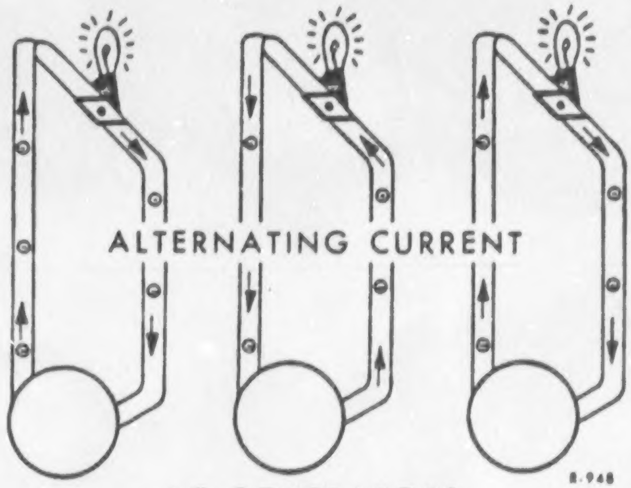
Electrical energy is commonly generated in two forms: direct current (dc), which is used in automotive systems, and alternating current (ac), which is used to operate most household appliances.

In direct current the electrons flow around the circuit in one direction only.

When an alternating current generator is used, the electrons flow back and forth as the polarity of the voltage changes (see illustration). The figure shows three impulses. Household ac is generally 60 cycles per second; that is, 60 impulses in each direction each second.

When an electrical appliance is unplugged from a wall receptacle a flash may be seen. This flash is electricity traveling through the air and is called an "arc."





AC GENERATORS

QUESTIONS 64 through 66.

After the corresponding number on your response sheet black out the letter that identifies each definition on the right with the term it defines as given in the left column.

64. Alternating current.

65. Arc.

66. Direct current.

A. The travel of electricity through the air when it produces a flash.

B. Current that changes its direction of flow at regular intervals.

C. Current that flows in one direction only.

//////////////////////////////

64. B. 65. A. 66. C.

QUESTIONS 67 through 73.

After the corresponding number of your response sheet black out the letter that identifies each term on the right with its definition as given in the left column.

67. Current that flows in one direction.

68. Dirty or loose connections, cable too small, or frayed.

69. Where a bare wire is touching another bare wire, giving the current a different path to travel than that intended.

70. Current that changes its direction of flow at regular intervals.

71. A break or lack of contact in an electrical circuit.

72. The travel of electricity through the air where it produces a flash.

73. Where a bare wire is touching the frame or another metal surface that is grounded.

A. Open circuit.

B. Alternating current.

C. Short circuit.

D. Arc.

E. Excessive resistance.

F. Direct current.

G. Unwanted ground.

////////////////////////////

67. F 68. E 69. C 70. B 71. A

72. D 73. G

Note: If you found that you could not accurately match the terms and definitions above without looking at the answers, go back and study those terms that gave you trouble before continuing any farther with this program.

Frame 32.

QUESTIONS 74 through 81.

After the corresponding number on your response sheet black out the letter that identifies each term on the right with its definition as given in the left column.

74. A unit of measurement of resistance.

75. The pressure or force of an electrical circuit that causes current to flow.

76. That property of an electrical circuit that tends to prevent or reduce current flow.

77. A unit of measurement of current flow.

78. A unit of measurement of electrical pressure (electromotive force).

79. A particle in an atom that contains no electrical charge.

80. A positively charged particle in an atom.

81. A negatively charged particle in an atom.

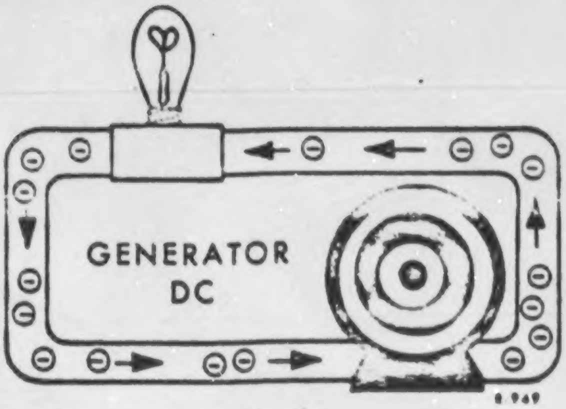
A. Resistance.
B. Volt.
C. Ampere.
D. Voltage.
E. Ohm.
F. Electron.
G. Proton.
H. Neutron.

//////////////////////////////

74. E   75. D   76. A   77. C
78. B   79. H   80. G   81. F

Note: If you found that you could not accurately match these terms and definitions without looking at the answers, study the terms that gave you trouble before proceeding any further in the program.

A generator can be used to produce electrical energy. In an automobile, the engine turns the dc generator by mechanical linkage (drive belt). Since a generator requires the use of mechanical energy and produces electrical energy, the generator can be described as a device that converts mechanical energy to electrical energy.



QUESTION 82.

A generator is a device that converts

a. chemical energy to electrical energy.

b. mechanical energy to electrical energy.

c. electrical energy to mechanical energy.

d. chemical energy to mechanical energy.

//////////////////////////////

b. is correct

Electricity can be used to operate an electric motor which in turn cranks the engine (automobile starter) or some other device that can be linked mechanically to the motor. Since an electric motor uses electricity to produce mechanical energy it (the motor) can be described as a device that converts electrical energy to mechanical energy. A current-carrying conductor, in a magnetic field, will be pushed out sideways.

Frame 54.

QUESTION 83.

A motor is a device that converts

a. chemical energy to mechanical energy.

b. chemical energy to electrical energy.

c. mechanical energy to electrical energy.

d. electrical energy to mechanical energy.

//////////////////////////////

d. is correct

Many electrical devices have a movable part called an "armature." A dc generator produces electricity by rotating the armature through a magnetic field. A motor runs because the magnetic fields act upon the armature causing it to rotate. A relay or a doorbell operates when the magnetic field attracts the armature.

QUESTION 84.

An armature is defined as the

a. movable part of an electromagnetic device.

b. device that changes electrical energy to mechanical energy.

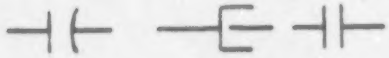
c. part of a relay or bell that produces a magnetic field.

d. device that changes mechanical energy to electrical energy.

//////////////////////////////

a. is correct

CAPACITOR SYMBOLS



Electricity is produced in generators by changing mechanical energy into electrical energy and in batteries by changing chemical energy into electrical energy. Although batteries are often called "storage" batteries they actually produce, not store, electricity. The only device that stores electricity is the capacitor (condenser). Notice in the illustrations above the symbols used to represent capacitors. A capacitor consists of two wires connected to metal plates which are separated by a very thin insulating material. A capacitor is charged with electricity by applying a voltage between the two wires. This action causes a build up of a positive charge on one plate and a negative charge on the other plate. The unit of measurement of capacitance is a "farad." In terms of capacitance a farad is a rather large unit of measurement, therefore, most capacitors are rated in terms of "microfarads." A microfarad is one-millionth of a farad.

QUESTIONS 85 and 86.

85. A capacitor is a device that

a. changes chemical energy to electrical energy.

b. produces an arc at the ignition points of automotive vehicles.

c. stores electrical energy.

d. produces electricity.

86. The unit of measurement of the capacity of a capacitor is the

a. volt.

b. farad.

c. ampere.

d. ohm.

//////////////////////////////

85. c 86. b

Frame [illegible].

QUESTIONS 87 through 91.

After the corresponding number on your response sheet black out the letter that identifies each term on the right with its definition as given in the left column.

87. A device that changes electrical energy to mechanical energy.

88. A unit of measurement of the capacity of a capacitor (condenser).

89. A device that changes mechanical energy to electrical energy.

90. A device that stores electrical energy.

91. The movable part of an electromagnetic device.

A. Capacitor.

B. Generator.

C. Motor.

D. Farad or microfarad.

E. Armature.

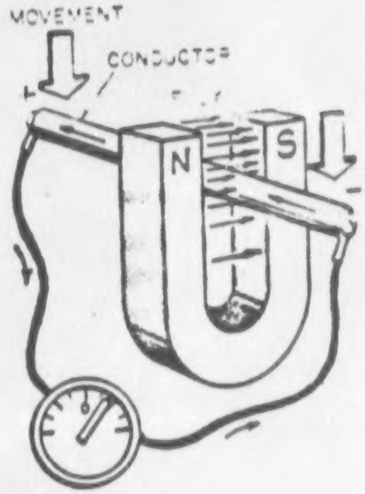
////////////////////////////

87. C 88. D 89. B

90. A 91. E

Note: If you found that you could not accurately match the terms and definitions above without looking at the answers, go back and study the terms that gave you trouble before proceeding any further with this program.

If a conductor is moved through a magnetic field, as in the accompanying illustration, an emf (electromotive force) is generated in the conductor causing current to flow through it.



QUESTION 92.

Electricity can be produced mechanically if you have

a. a conductor and a magnetic field.

b. motion and a magnetic field.

c. a magnetic field, a closed conductor, and relative motion.

d. motion and a conductor.

//////////////////////////////

c. is correct

The armature of a generator supplies the conductor used in producing electricity. The rotation of this armature supplies the motion and the field windings supply the magnetic field. When a conductor is moved through a magnetic field the resultant current flow is said to be produced by "electromagnetic induction."

Frame 33.

QUESTIONS 93 through 97.

93. Electricity is produced mechanically by a/an

a. battery.
b. generator.
c. transformer.
d. electromagnet.

94. How does a generator produce electricity?

a. By electromagnetic induction.
b. By electromotive force.
c. By chemical action.
d. Statically.

95. What are the three things required to produce electricity by electromagnetic induction?

a. A generator, a battery, and a transformer.

b. A chemical, a force, and an electromagnet.

c. Spongy lead, lead peroxide, and electrolyte.

d. Motion, a magnetic field, and a closed conductor.

96. A generator produces electricity

a. chemically.

b. magnetically.

c. residually.

d. mechanically.

97. The production of electricity in a generator is called

a. chemical action.

b. residual magnetism.

c. electromagnetic induction.

d. static electricity.

//////////////////////////////

93. b 94. a 95. d

96. d 97. c

REVIEW

Study this chart and then answer the questions asked below by writing the answers in the spaces provided on your response sheet.

VOLTAGE	CURRENT	RESISTANCE
1. The property of an electrical circuit that causes current flow. 2. The unit of measurement is the "volt." 3. Voltage is measured with a voltmeter. 4. The symbol for voltage is "E." REMEMBER: THE VOLTMETER MUST BE CONNECTED IN PARALLEL TO MEASURE THE VOLTAGE OF A CIRCUIT.	1. The movement of free electrons in a circuit is called "current." 2. The unit of measurement is "ampere" or "amp." 3. Current is measured with an ammeter. 4. The symbol for current is "I." REMEMBER: THE AMMETER MUST BE CONNECTED IN SERIES TO MEASURE THE CURRENT IN A CIRCUIT.	1. The opposition to current flow in an electrical circuit is called "resistance." 2. The unit of measurement is the "ohm." 3. Resistance is measured with an ohmmeter. 4. The symbol for resistance is "R."

Note: Cover the chart above with your mask and answer each question. After you have answered the questions you may check your answers by referring to the chart above.

QUESTIONS 98 through 107

98. Opposition to current is
99. Causes current to flow
100. Unit of measurement for R is
101. Unit of measurement for E is
102. Unit of measurement for I is
103. Measures current.
104. Measures resistance.
105. Measures voltage.
106. Must be connected in series.
107. Must be connected in parallel.

RESPONSES

Voltage
Resistance
Amperes
Ohms
Volts
Voltmeter
Ammeter
Ohmmeter

Frame 40.

After the corresponding number on your response sheet black out the letter that identifies each term on the right with its definition as given in the left column.

108. A unit of measurement of resistance.

109. The pressure or force in an electrical circuit that causes current to flow.

110. That property of an electrical circuit that tends to prevent or reduce current flow.

111. A unit of measurement of current flow.

112. A unit of measurement of electrical pressure (electromotive force).

113. A particle in an atom that possesses no electrical charge.

114. A positively charged particle in an atom.

115. A negatively charged particle in an atom.

A. Resistance.

B. Volt.

C. Ampere.

D. Voltage.

E. Ohm.

F. Electron.

G. Proton.

H. Neutron.

//////////////////////////////

108. E 109. D 110. A 111. C

112. B 113. H 114. G 115. F

QUESTIONS 116 through 122.

After the corresponding number on your response sheet black out the letter that identifies each term on the right with its definition as given in the left column.

116. Current that flows in one direction.

117. Dirty or loose connection, cable too small, or frayed.

118. Where a bare wire is touching another bare wire giving the current a different path to travel than that intended.

119. Current that changes its direction of flow at regular intervals.

120. A break or lack of contact in an electrical circuit.

121. The travel of electricity through the air where it produces a flash.

122. Where a bare wire is touching the frame or another metal surface that is grounded.

A. Open circuit.

B. Alternating current.

C. Short circuit.

D. Arc.

E. Excessive resistance.

F. Direct current.

G. Unwanted ground.

//////////////////////////////

116. F 117. E 118. C 119. B

120. A 121. D 122. G

LAST CHANCE! If you found that you could not accurately match the terms and definitions of any of the last two frames without looking at the answers study those terms that gave you trouble.